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STRUCTURE AND RELATIONS OF MYLOSTOMA.

By C. R. Eastman.

With Five Plates.

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No. 1.— *Structure and Relations of Mylostoma.* By C. R. Eastman.

It is proposed in the present communication to point out the intimate structural resemblance between Mylostoma and Dinichthys, and, taking these forms as typical examples of Arthrodires, to compare their general organization with that of Neoceratodus and other Dipnoan fishes. Evidence is presented for associating Arthrodires with Dipneusti, and their relations to fossil and recent members of the subclass are considered. A summary is also given of the leading facts in the evolutionary history of Dipnoans since their first appearance in the Lower Devonian until their decadence bordering upon extinction in the modern fauna.

One of the chief contentions of the present paper is that which relates to the systematic position of Arthrodires; and as scarcely any two modern writers are agreed upon this matter, it is instructive to review the more prevalent theories concerning the relations of these extinct forms to other fishes. The "family Placodermi" of M'Coy was instituted in 1848 for the reception of Coccosteus, Pterichthys, and Asterolepis, and for more than forty years these genera and their allies were considered to form a natural group of Ganoidei. Elevated by subsequent writers to ordinal and even higher rank, it remained for Cope, in 1889, to recognize the heterogeneous nature of this assemblage, and to initiate its disruption. He first proposed the removal of Asterolepis from the class of Pisces altogether, and at the same time referred Coccosteans provisionally to the Crossopterygii. (Amer. Nat., 1889, **32**, p. 856). Shortly afterwards, however, following Smith Woodward's suggestion, the several families of Coccosteus-like fishes were grouped, under Woodward's new term of Arthrodira, in a separate order of Dipnoans.[1] This arrangement obviously implied, though it had not as yet been demonstrated, that the Arthrodiran skull was truly autostylic, and that a secondary upper jaw was not developed. One of the chief reasons which influenced the novel association of Arthro-

[1] Cope, E. D. Syllabus of lectures on geology and paleontology. Philadelphia, 1891, p. 14.

dires with Dipnoans was the parallelism, previously noted by Newberry,[1] between the dentition of Dinichthys and that of Protopterus. The absence of any indication of a hyomandibular bone, even in the most admirably preserved skeletons, and of more than a single ossification in the mandibular ramus, were considered sufficient reasons for excluding Arthrodires from Teleostomes.

This provisional classification of Arthrodires with Dipnoans met with an indifferent reception on the part of most paleontologists, and was afterwards rejected by some of its early supporters, notably Traquair and Bashford Dean. Smith Woodward himself conceded, in 1898, that "the systematic position of this extinct order [Arthrodira] is indeed doubtful."[2] Traquair's defection dates from 1900, when he declared, in his Bradford address, in favor of considering Arthrodires as "Teleostomi belonging to the next higher order, Actinopterygii."[3] The following year Dean expressed the radical view that they were not fishes at all, but representatives of a distinct class, named by him Arthrognathi, and conceived to have possible kinship with Ostracophori.[4] It was even allowed that subsequent researches might demonstrate a union between Ostracophores and Arthrognaths, whereby M'Coy's group of Placodermata would be restored. This was a complete reversal of his former view that the "jaws, specialized dentition, fin-spines, and highly evolved pelvic fins at once separate this group from the lowly Ostracoderms."[5]

By far the most comprehensive definition of the term Placodermata is that of Jaekel, in 1902, whereby the Pteraspids, Tremataspids, Psammosteids, Cephalaspids, Asterolepids, and Coccosteans were all embraced within a single group.[6] This assemblage was modified a twelvemonth later, however, in that the two last-named divisions were bracketed together under the new division of "Temnauchenia," in contradistinction from the so-called "Holauchenia," — a collective designation applied to Pteraspids, Trematapids, Cephalaspids, Drepanaspids, and

[1] Newberry, J. S. Descriptions of fossil fishes. Rept. Geol. Surv. Ohio. Paleont., 1875, **2**, p. 5.

[2] Woodward, A. S. Outlines of vertebrate paleontology. Cambridge, 1898, p. 64.

[3] Traquair, R. H. Vice-Presidential address. Rept. Brit. Assoc. Adv. Sci. Bradford meeting, 1900, p. 779.

[4] Dean, B. Palaeontological notes. Mem. N. Y. Acad. Sci., 1901, **2**, p. 113.

[5] Dean, B. Fishes, living and fossil. New York, 1895, p. 130.

[6] Jaekel, O. Ueber Coccosteus und die Beurtheilung der Placodermen. Sitz. Gesell. Nat. Freunde, Berlin, 1902, p. 103.

the Birkeniidae. All of these forms, or if the expression be permitted, Placoderms in the Jaekelian sense, were considered to be true fishes.[1] It was further maintained by the same author on more than one occasion that Coccosteans are ancestral to Chimaeroids, an opinion that may be compared with Newberry's idea that Protopterus and Lepidosiren are modern survivals of Dinichthys.[2] Newberry and Jaekel thus stand alone in the recognition of any descendants of Arthrodires.

We may now pass rapidly in review the minor fluctuations of opinion that are apparent during the last few years. Dr. O. P. Hay, in his Catalogue of fossil Vertebrata of North America (1902), employs the term Placodermi for both Arthrodires and Asterolepids, placing them in the same subclass as Dipnoans. Arthrodires and Ostracophores are awarded each the rank of a separate subclass in the English edition of von Zittel's Textbook of paleontology, the author having discountenanced an association between Coccosteans and Dipnoans. In a remarkable paper by C. T. Regan, published in 1904, the Placodermi are re-established so as to include the Coccosteidae, Asterolepidae, and Cephalaspidae, all being united in a single order of Teleostomes. During the same year Professor Bridge expressed the view, in the volume on Fishes in the Cambridge natural history, that Coccosteans are "a highly specialized race of primitive Teleostomi," and compared their cranial roof-plates with those of typical bony fishes. Both in this work and in an elaborate monograph on the skull in modern Dipnoans, this author dissents emphatically from the opinion that Arthrodires and lung-fishes are at all closely related. Thus, in the volume on Fishes, at page 537, we read as follows: —

"The Arthrodira have been regarded as armoured Dipneusti, a view which is mainly based on their supposed autostylism and the nature of the dentition. But this autostylism has yet to be verified, and, if proved, the possibility that it may be a secondary feature, associated with the evolution of a peculiar dentition, must not be forgotten. Much more may be said for their claim to be regarded as a highly specialized race of primitive Teleostomi. Besides a well-developed lower jaw, bones comparable to the elements of a secondary upper jaw are known, and in a general way the disposition of the cranial roofing bones, and the arrangement of the endoskeletal elements of the pelvic fins, tend to conform to the normal Teleostome type. In fact, Dr. Traquair has expressed the opinion that the Arthrodira are Teleostomi and Actinopterygii."[3]

[1] Jaekel, O. Ueber die Organisation und systematische Stellung der Asterolepiden. Zeit. Deutsch. Geol. Gesell., 1903, **55**, p. 55.

[2] Newberry, J. S. Rept. Geol. Surv. Ohio. Paleont., 1875, **2**, p. 15.

[3] In his latest reference to this subject, however, they are stated by Traquair to be of uncertain subclass. *Cf.* Trans. Roy. Soc. Edinb., 1903, **40**, p. 732.

In two articles on Dinichthyid remains, published in 1905, Mr. L. Hussakof[1] refers to them as "Placoderms," evidently using the term in its familiar acceptation. Their position is also left undetermined by Prof. E. Ray Lankester, in his interesting lectures on Extinct animals, recently published.[2] Dr. F. A. Lucas's popular treatise on Animals before man in North America places them in association with lung-fishes, in accordance with Smith Woodward's ideas. One other popular handbook claims attention, not only because it is an extremely useful work covering the whole subject of fishes, but also because of the author's acquaintance with fossil as well as recent forms. We refer to President D. S. Jordan's Guide to the study of fishes (New York, 1905), in the first volume of which (page 582) the relations of Arthrodires are discussed as follows: —

"These monstrous creatures have been considered by Woodward and others as mailed Dipnoans, but their singular jaws are quite unlike those of the *Dipneusti*, and very remote from any structures in the ordinary fish. The turtle-like mandibles seem to be formed of dermal elements, in which there lies little homology to the jaws of a fish and not much more with the jaws of Dipnoan or shark.

The relations with the Ostracophores are certainly remote, though nothing else seems to be any nearer. They have no affinity with the true Ganoids, to which vaguely limited group many writers have attached them. Nor is there any sure foundation to the view adopted by Woodward, that they are to be considered as armored offshoots of the Dipnoans."

Again, at page 445 of the same volume, occurs this passage: —

"These creatures have been often called ganoids, but with the true ganoids like the garpike they have seemingly nothing in common. They are also different from the Ostracophores. To regard them with Woodward as derived from ancestral Dipnoans is to give a possible guess as to their origin, and a very unsatisfactory guess at that."

Finally, reference may be made to a paper published early in the present year, in which the writer[3] endeavored to show that the dentition of Arthrodires belongs distinctly to the Dipnoan type, and that real homologies exist between their cranial roof-plates and those of the living Neoceratodus. Indeed, the modern form was held to bear as intimate structural resemblance to Coccosteans on the one hand, as

[1] Hussakof, L. Notes on the Devonian "Placoderm," Dinichthys intermedius Newb. Bull. Amer. Mus. Nat. Hist., 1905, **21**, p. 27–36. On the structure of two imperfectly known Dinichthyids. *Ibid.*, p. 409–414.

[2] Lankester, E. R. Extinct animals. New York, 1905, p. 256.

[3] Eastman, C. R. Dipnoan affinities of Arthrodires. Amer. Journ. Sci., 1906, ser. 4, **21**, p. 77–89.

to Ctenodipterines on the other, although conforming in certain respects more closely than either to the hypothetical common ancestor from which all three types — Ceratodonts, Arthrodires, and Ctenodipterines — have been derived.

The position maintained in this last communication is adhered to, and it is believed that sufficient evidence has now been accumulated to sustain its correctness. Heretofore, in default of positive evidence, writers have been unable to demonstrate the truth of any one of the various conjectures put forward to explain the nature of Arthrodires. However plausible one or another of these may have appeared, however firmly they have been insisted upon, it must be remembered that a suggestion remains only a suggestion, and an hypothesis an hypothesis, until its correctness is clearly proved. Not without reason is it observed in one of the Socratic dialogues, that "mere beliefs and opinions are, like the statues of Daedalus, runaway things; not until they have been tied down by the chain of causal sequence do they stand fast and become in the true sense knowledge." (*Meno*, 159 D).

What constitutes "reasoned interconnection," as Plato calls it, in the present case, lies in the recognition of actual, definite, and precise homologies between Arthrodires and typical Dipnoans, which have hitherto escaped attention. That the significance of certain Arthrodiran characters has not been fully appreciated heretofore is due in large measure to the lack of sufficiently instructive material; and in part, also, to wrong interpretation of existing materials. By a fortunate chance the former of these deficiencies is now remedied, valuable enlightenment being afforded by the type of a new genus of Arthrodires from the Portage of western New York, presently to be described under the name of Dinomylostoma. It is hoped, also, that the second of these difficulties may be removed by means of a novel interpretation of the jaw-parts of Coccosteans and Mylostomids, such as is hereinafter set forth. Altogether, it would appear that a sound basis is now provided for upholding the following general propositions: —

1. Cranial roof-plates have undergone corresponding reduction and have become arranged after essentially the same pattern, both in Arthrodires and primitive Ceratodonts.

2. Neoceratodus recalls throughout its entire organization, save only for the absence of body armoring, the principal features of Arthrodires; resemblances which form too large an aggregate to be explained through parallelism.

3. It is impossible to regard Neoceratodus as the degenerate de-

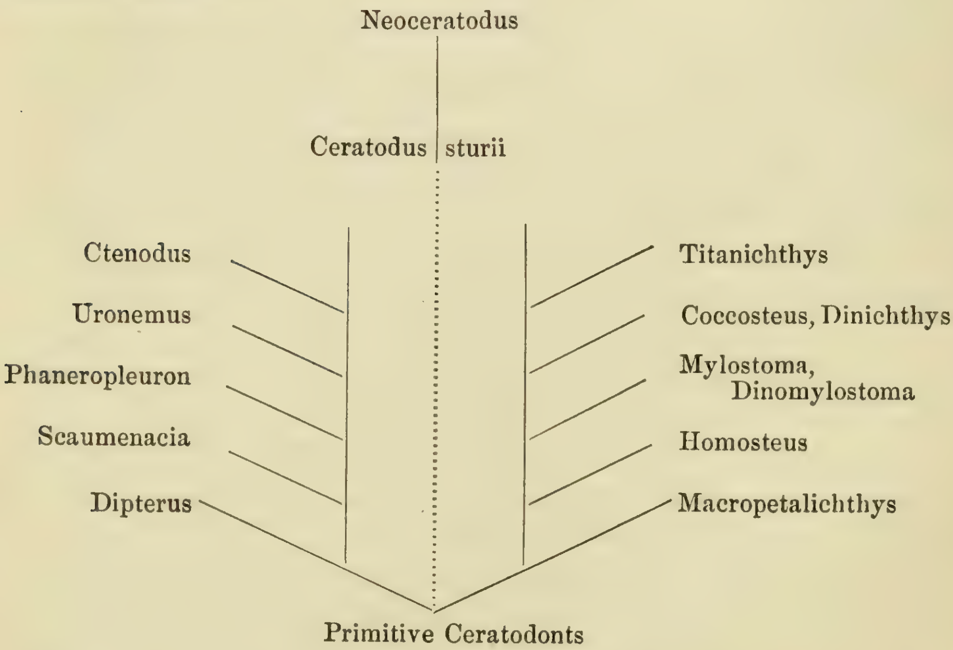
scendant of *both* Ctenodipterines and Arthrodires, nor of either group to the exclusion of the other. Since, however, it partakes of the characters of both, community of origin is necessarily presupposed for all three groups.

4. Arthrodires and Ctenodipterines may be regarded as specialized offshoots which diverged in different directions from the primal Dipnoan stem; and only the more generalized descendants of the original stock have continued to survive until modern times.

5. The primordial stock must have been autostylic, diphycercal, without a secondary upper jaw and dentigerous dentary elements, and with a Uronemus-like or Dipterus-like dentition; characters which do not permit us to ascribe the ultimate origin of Dipnoans to the Crossopterygii, but suggest rather a descent from Pleuracanthus-like sharks.

6. The recognition of Arthrodires as an order of Dipneusti precludes their association with Ostracophores in any sense whatever. The recently revived group of "Placodermata" is, therefore, an unnatural assemblage and should be abandoned.

7. In the light of present information, progressive modifications amongst early Dipnoans may be represented graphically after some such scheme as follows: —



With this statement of the general nature of the problem, our task is to substantiate the claim in regard to the close structural agreement

between Arthrodires and Ceratodonts. First and most important of all, the characters furnished by the dentition may be considered; and we shall endeavor to show that Dinichthys and Mylostoma represent the same modifications in the ancient fauna as are displayed by Protopterus and Neoceratodus in the recent, so far as dental characters are concerned.

Dentition of Dinichthys and Neoceratodus compared. — It is admitted by all writers that Neoceratodus, as compared with the two other surviving genera of lung-fishes, represents a relatively early larval stage of development; nor is it questioned by any one that the trenchant dental plates of Protopterus and Lepidosiren are not mere variants of the Ceratodont type. This much being already clear, it is but a short step further to see that the dentition of Coccosteus and Dinichthys has been similarly derived. Certainly no difficulty is offered by the so-called "premaxillary" teeth of Dinichthys, which are the precise equivalent of the vomerine pair in modern Dipnoans, as was long ago pointed out by Dr. Theodore Gill.[1] As for the characteristic tritoral plates in upper and lower jaws of Ceratodonts, these occur normally in Mylostoma, but in Dinichthys have become rotated so as to stand upright in the jaws, their outer denticulated margins functioning against one another like the blades of a pair of shears. An inkling as to how this variation was brought about is afforded by the Triassic *Ceratodus sturii* Teller,[2] which may be taken to represent an incipient stage of metamorphosis. The dental plates of this form are seen to be turned more or less on edge, the corrugations interlocking in opposite jaws when the mouth is closed, and a rudimentary beak being developed in front which recalls the well-known tooth-like projection in Dinichthyid mandibles.

As for the so-called "maxillary" or "shear-tooth" of Dinichthys, this corresponds plainly to the triturating upper (palato-pterygoid) dental plates of Ceratodonts, turned rather more upright than in *C. sturii*; and its anterior process or "shoulder" is represented by the forwardly placed ascending process of modern forms.

The functional lower jaw of Arthrodires agrees with that of other Dipnoans in that the mandibular dental plate is supported solely by the splenial, and no true dentary element is present. The Ctenodipterine mandible, as compared with that of other *Dipneusti*, is the most complicated, being composed of a greater number of pieces, more extensively ossified, and covered externally with a ganoine investment. Consider-

[1] Rept. Geol. Surv. Ohio. Paleont., 1875, **2**, p. 7.

[2] Teller, F. Ueber den Schädel eines fossilen Dipnoërs. Abhandl. k. k. Reichsanst., Wien, 1891, **15**, Plate iv.

able simplification is to be observed amongst modern Sirenoids, in that the articular element is not differentiated from the Meckelian cartilage, the ensheathing angular has become reduced in the two more specialized genera to a mere splint-like rudiment, and in the same genera the flat triangular piece called by Huxley the "dentary," by Fürbringer[1] the "submandibular," has disappeared entirely. Still further reduction is evident amongst Arthrodires, where there are no bones ensheathing Meckel's cartilage externally, and the only ossifications thus far recognized consist of the splenial and mandibular dental plate. All the best known genera display a conspicuous groove along the antero-inferior border of the splenial, passing underneath and to the inner side of the dental plate proper, and terminating a little short of the symphysis. Its general appearance, position, and direction at once recall the very similar groove in Protopterus, hence it is natural to attribute to it a corresponding function. In it were lodged remnants of the Meckelian cartilage, precisely as in living forms.[2]

The suggestion has been made by one or two recent writers that the jaws of Arthrodires are non-homologous with those of ordinary fishes. Dean, for instance, supposes them to have originated from merely dermal ossifications, and to be in nowise derived from visceral arches. Unessential structural differences, and assumed functional differences, such as mobility of the mandibular rami in a manner wholly unique amongst Chordates, are urged in support of this novel idea. Whether we compare the Arthrodiran lower jaw with that of Ctenodipterines, as Sagenodus,[3] for example, or of modern Sirenoids, the obvious similarity of all the parts, relations of the Meckelian cartilage, and insensible transition between the splenial and mandibular dental plate as regards

[1] Fürbringer, K. Beiträge zur Morphologie des Skeletes der Dipnoer, etc. Semon's Zool. Forschungsreisen in Australien. Jena Denkschr., 1904, **4**, p. 442. Miall and Traquair employ Huxley's designation; the same element is also named "predentale" by Van Wije, and "dermomentale" by Fritsch. Its origin appears to be conditioned by the presence of mandibular sensory canals, the bone being formed around them. When canals are lacking, as in *Protopterus* and Arthrodires, no submandibular occurs.

[2] Fürbringer, K. *Op. cit.*, p. 481, Plate 39, Fig. 28. Wiedersheim, R., Morpholog. Studien. Jena, 1880, **1**, p. 55, Plate 2, Figs. 3, 8.

[3] The splenial, for instance, is notably elongated in the form figured by T. Atthey under the name of *Ctenodus obliquus* in the Ann. Mag. Nat. Hist., 1875, ser. 4, **15**, p. 390, Plate 19, Fig. 2. By Smith Woodward this species is considered identical with *Sagenodus inaequalis* Owen. In *Sagenodus pertenuis*, from the Permian of America and Russia, the dental plates develop sharp cutting edges. See Amer. Nat., 1904, **37**, p. 493–495.

microscopic structure,[1] demonstrate in clearest possible manner that definite homologies exist. Not only can there be no question as to real homology, but it is further evident that one general type of mandible is common to all Dipnoans, only amongst Arthrodires this type is resolved to its simplest terms. So far as the present writer is aware, no adequate cause has been shown for supposing that the jaws of Arthrodires were capable of anomalous movements, and the notion that the mandibular rami were not rigidly united with each other at the symphysis may be regarded as slender as the seven lean kine. That the vomerine teeth, at least, were immovably attached to the headshield is proved by their occasional fusion with it in Dinichthys, as in a specimen belonging to the British Museum (Cat. No. P 9490), and presumably also in the complete skull described by Newberry [2] "with the great premaxillary teeth in place," immediately behind which were the "maxillaries." There can be no question that the upper pavement dentition of Mylostomids was absolutely fixed. Under such conditions it is inconceivable that the mandibular rami were capable of torsion, and of separation and approximation from each other at their anterior extremities. But it has been argued that such movements are implied by the presence of symphysial denticles in forms like Coccosteus and Diplognathus. The logic involved does not appear to be particularly convincing. In the first place it is uncertain whether these denticles were really functional. And in the second place, even if they were, their origin is best explained as a reminiscence of primitive conditions, such as are to be inferred from the ontogeny of Neoceratodus.[3]

Dentition of Mylostoma and Neoceratodus compared. — The large tritoral upper dental plates of Mylostoma present such an obvious similarity to the well-known crushing plates of typical Dipnoans that, supposing

[1] It has been shown by Claypole in the Proc. Amer. Micros. Soc., 1894, **15**, p. 189–191, that the functional margin of a jaw element in Dinichthys differs from the remaining portion (splenial) only in its denser structure. Identical conditions exist amongst fossil and recent Dipnoans. Thus Günther, in his description of Neoceratodus, remarks that the substance of the splenial "passes so gradually into that of the tooth that it is only by the difference in shade of color that the boundary line between osseous base and dentinal crown is indicated. . . . In our specimens the structure of the bony base of the tooth differs in nothing from that of the remainder of the dentary bone [*i.e.*, splenial]: there is the same spongeous structure, the same proportion of bone-corpuscles, etc." — Phil. Trans., 1871, **161**, p. 519.

[2] Newberry, J. S. Monogr. U. S. Geol. Surv., 1889, **16**, p. 146.

[3] Semon, R. Die Zahnentwickelung des Ceratodus forsteri. Sitz. Gesell. Morph. Phys. München, 1899, **15**, p. 75–85. Also Zool. Forschungsreisen in Australien. Jena Denkschr., 1901, **4**, p. 115–133.

they had always been found in the detached condition, without being associated with a Dinichthys-like mandible or other parts suggestive of Arthrodires, no one would question the propriety of referring them to Dipnoans. In general form, mode of attachment, and microscopic structure, they differ in nowise from the characteristic palato-pterygoid dentition of lung-fishes. If it be objected that they have neither tuberculated surfaces nor crenulated outer margins, it must be remembered that various Dipnoan genera are known which have perfectly smooth dental plates. The plates themselves, therefore, reveal no characters which enable us to distinguish them from the Dipnoan type of upper dentition.

It has been demonstrated, however, in the most convincing manner, that these upper tritoral plates of Mylostoma belong to Arthrodiran fishes essentially like Dinichthys, except that the dentition is adapted for crushing instead of cutting; in other words, the two genera mentioned present an interesting parallel, as regards their dentition, to the modern Neoceratodus and Protopterus. It follows as a matter of course that the jaw-parts of the two recent and the two fossil genera must be respectively homologous, inasmuch as common ancestry is implied for the members of either pair. Great as may appear at first sight the differences between the Mylostoma and Dinichthys form of dentition, they are nevertheless reducible to a common plan, and this common plan is identical with that typified by Neoceratodus. In the first place it is to be noted that the two Arthrodiran genera under comparison have a single, and somewhat similar, pair of vomerine teeth, as do also modern Dipnoans. Next it will be observed that a like form of mandible is present in both genera, bating only that in Mylostoma the dental plate lies horizontally expanded, and in Dinichthys it is turned vertically, so that what was formerly the denticulated outer margin now becomes the functional cutting edge. There remains finally the palatal dentition to be considered, and here the fact requires explanation that two tritoral pairs of dental plates occur behind the vomerines in Mylostoma, as opposed to the single pair of "shear-teeth" in Dinichthys, which have already been interpreted as the morphological equivalent of the palato-pterygoid dental plates of Ceratodonts. Enlightenment on this point is furnished by the ontogeny of Neoceratodus, which teaches that the discrepancy is more apparent than real; for, as shown by Semon,[1] the dental plates of the modern genus arise through concrescence of conical denticles, which are at first disposed so as to form two pairs of palato-pterygoid

[1] *Loc. cit.*, 1899, and 1901.

plates, arranged as in Mylostoma, these afterwards fusing into one. Neoceratodus therefore reproduces ephemerally a stage which remains permanent in the Devonian genus, and is probably to be regarded as an inheritance of primitive conditions.

Sufficient arguments have now been given, we think, to support the claim that the dentition of Mylostoma and Dinichthys is constructed distinctly upon the Dipnoan type. We learn from recent forms that the external ensheathing bones of the mandible may become greatly reduced. In the Arthrodiran jaw this process has merely been carried a little further than in Protopterus. The presence of a supernumerary pair of dental plates in Mylostoma is satisfactorily accounted for by the ontogeny of Neoceratodus, which reveals the primitive nature of Mylostomid type of dentition, and suggests for it a common origin with the Ceratodont. Indeed, the evidence derived from this latter source shows that Mylostoma has departed less widely from primitive Ceratodonts with respect to its dentition than have true Dipterines; for amongst the latter no vomerine teeth occur, nor is any form known which has retained more than a single pair of palato-pterygoid dental plates, whereas their ancestors may reasonably be presumed to have had two. This point is in harmony with other facts making for the conclusion that modern lung-fishes are not directly descended from Dipterines.

Cranial characters indicating Dipnoan affinities of Arthrodires.— From the interpretation of jaw-parts just given, it is obvious that no secondary upper jaw occurs amongst Arthrodires. Certainly the suborbital, which is simply a cheek-plate, has nothing whatever in common with a maxillary arch, nor is there the slightest reason for believing that it supported, or was otherwise associated with, or even in contact with the "shear-tooth" in Dinichthys. Aside from the suborbital and dental elements already accounted for, there are absolutely no plates left which can by the greatest stretch of imagination be homologized with the maxillae and premaxillae of ordinary fishes. We are therefore prohibited from classing Arthrodires amongst Teleostomes, and at the same time must recognize their agreement with Dipnoans in one of their most distinctive characteristics.

Another important fact must also be considered. It is well understood that the cranial roofing-bones of modern lung-fishes are not readily to be homologized with those of Ctenodipterines, or indeed of any other group with the exception of Arthrodires. Now, how are we to explain this remarkable coincidence except upon the hypothesis of common

descent? It may be well at this point to inquire into the question of homologies a little more fully.

Various Arthrodiran genera may be selected for comparison with Neoceratodus, and the cranial structure of the two types be examined in most critical light; it will be found that intimate correspondence exists throughout. Inasmuch, therefore, as the skull of typical Arthrodires was constructed upon essentially the same model as in Neoceratodus, the latter becomes a standard for interpreting certain minor details which have hitherto been misunderstood. These we shall have occasion to refer to presently. In comparing the cranial pattern of the Ceratodont and Arthrodiran type, it will not do to confine our attention to any one genus of the latter; we must consider the range of variation exhibited by the group as a whole. Thus, at first sight, it would seem almost impossible to coördinate the median series of plates in Neoceratodus (Fig. B) with those of Dinichthys (Fig. A), although the lateral

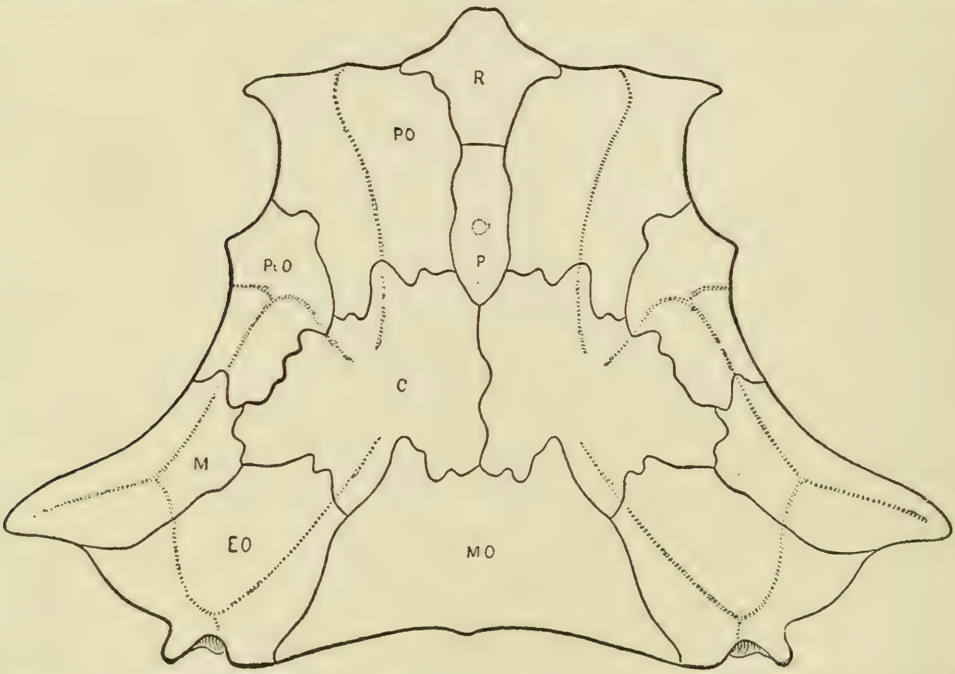


FIG. *A.* — *Dinichthys pustulosus* Eastman. Middle Devonian; Iowa. Restoration of the headshield, dorsal aspect, × ½. C, central; EO, external occipital; M, marginal; MO, median occipital; P, pineal; PO, preorbital; PtO, postorbital; R, rostral or mesethmoid. Sensory canals represented by double dotted lines. Suborbital omitted.

series stand in sensible agreement. The equation is readily solved, however, by substituting Macropetalichthys in place of Dinichthys as an intermediate term of comparison, on the principle that things equal to the same thing are equal to each other. Both in Macropetalichthys and

Neoceratodus the median series is reduced to one anterior element, covering the pineal and rostral (or ethmoid) regions, and one elongated posterior element (*M O*), these two plates being suturally united with each other, and excluding the paired central elements from contact along the median line. Nevertheless in Protopterus the plates corresponding to the centrals are actually in apposition along the median

FIG. *B.*—*Neoceratodus forsteri* (Krefft). Dorsal aspect of cranial roof, drawn as if flattened out, and dermal plates lettered to correspond with those in Dinichthys. Cartilaginous elements (PO) dotted; suborbitals omitted. From a specimen in M. C. Z., × ½.

line for a certain distance anteriorly, and in Homosteus the median occipital is relatively more elongated than in Neoceratodus. The latter shows an abrupt downward deflection of the bone-substance along a portion of the posterior margin of the cranial roof. Like conditions are found in Macropetalichthys, even more conspicuously developed. Macropetalichthys and Homosteus both have the external occipital greatly enlarged at the expense of the central elements. Neoceratodus, on the other hand, has the centrals enlarged at the expense of the external occipitals (Fig. *B*, *EO*). In *Ceratodus sturii* these plates are more nearly as in Dinichthys.

The remaining elements of the cranial roof in Neoceratodus are easily

coördinated with those of typical Coccosteans, allowance being made for the fact that the preorbital in the modern form appears to have reverted to its primitive cartilaginous condition. Similar instances of reversion, or degeneration of membrane-bones, occur among Chondrosteans and Teleosts. A tendency toward reversion would seem to be indicated also by the external occipital along its inner border, and the small plates surrounding the orbits show imperfect ossification. The latter, according to the observations of Huxley, Traquair, and others, are sometimes inconstant in number, the suborbitals tending to become fused into a single piece not unlike that of typical Coccosteans (*cf.* Figs. C, D). The postorbitals of Neoceratodus are interpreted by Bridge[1] as remnants of an obsolescent supraorbital ring; by Fürbringer[2] as bones that have become newly formed about the sensory canals bounding the orbit, yet belonging properly to the cranial roof. The explanation here offered is that they are equivalent to the single large postorbital occurring on either side of the headshield in Arthrodires.

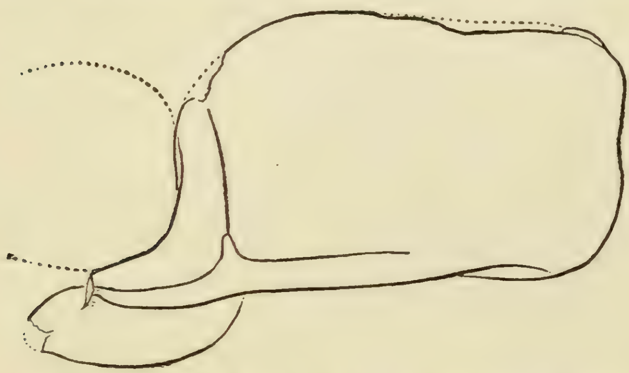


FIG. *C.* — Left suborbital plate of *Dinichthys terrelli* Newb., from the Cleveland shale of Ohio. External aspect, × ⅛.

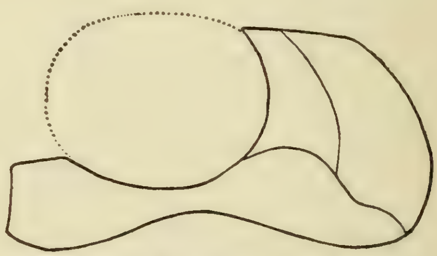


FIG. *D.* — The three plates forming collectively the suborbital of *Neoceratodus forsteri* (Krefft), drawn from the same specimen as shown in Fig. A. × ½.

Unlike Ctenodipterines, Neoceratodus retains throughout life a completely closed and almost entirely unossified chondrocranium, and this notable peculiarity would seem to be shared also by most Arthrodires. In Chelyophorus, however, two small ossifications occur in a position corresponding to the exoccipitals, and have been interpreted as such by Smith Woodward.[3] A somewhat

[1] Bridge, T. W. Morphology of the skull in Lepidosiren, etc. Trans. Zool. Soc. London, 1898, **14**, p. 355.

[2] Fürbringer, K. Beiträge zur Morphologie des Skeletes der Dipnoer. Jena Denkschr., 1904, **4**, p. 445.

[3] Woodward, A. S. Catalogue fossil fishes British Museum, 1891, pt. 2, p. 280.

nearer approach to Ctenodipterine conditions has been noted by Cope[1] in Macropetalichthys, where the space occupied by the chondrocranium is closed posteriorly by a thin osseous septum extending transversely across the headshield, and pierced in the middle by a triangular opening for passage of the notochord. The same genus is further remarkable for having a partially ossified parasphenoid, which is produced posteriorly beyond the transverse septum referred to as far as the hinder margin of the headshield, and supports the forward portion of the vertebral axis in a manner analogous to that in Neoceratodus and sturgeons. Mention may also be made in this connection of an undescribed Coccostean from the Devonian of Wildungen, which, according to Jaekel,[2] shows traces of an "echte Schädelkapsel mit deutlichem Occiput und Foramen magnum." Aside from these instances, no ossifications are known within the interior of the headshield of Arthrodires which can be associated with the chondrocranium. The presence of a pineal gland is distinctly indicated in most forms, its position being as in Neoceratodus.

Another point of resemblance between Arthrodires and typical Dipnoans is found in the disposition of the external nares. Dipnoans represent an advance over Elasmobranchs in that the oro-nasal grooves of the latter are converted into true nasal passages, and the olfactory pits communicate with the mouth by internal nostrils as in higher vertebrates. This modification is evidently to be associated with air-breathing habits, and, as pointed out by Huxley[3], suggests that the sense of smell is of value to these creatures. The occurrence of internal narial openings amongst Arthrodires would coincide with other evidence indicating Dipnoan relationships, and we may even attempt to define their position in at least one genus, as will be noted in the description of Dinomylostoma (p. 27). The large size of the supposed olfactory capsules in Dinichthys[4] may also be considered as implying a tolerably keen perception of odoriferous particles, which is dependent upon the

[1] Cope, E. D. On the characters of some Palaeozoic fishes. Proc. U. S. Nat. Museum, 1891, **14**, p. 453, Plate 29, Fig. 4, Plate 30, Fig. 5.

[2] Jaekel, O. Ueber die Organisation und systematische Stellung der Asterolepiden. Zeitschr. Deutsch. Geol. Gesell., 1903, **55**, p. 48.

[3] Huxley, T. H. On Ceratodus forsteri, etc. Proc. Zool. Soc. London, 1876, p. 27. Position of the anterior nasal apertures in Lepidosiren. *Ibid.*, p. 180.

[4] These are described as "optic capsules" by Newberry in his Monograph on the Palaeozoic fishes of North America, p. 146, Plate 7, Figs. 2, 2*a*. They are stated to occur "not always in the same position, but they were two in number, one on each side, and located well within and near the anterior extremity of the head."

act of sniffing; and this function can only be performed effectually when posterior nasal apertures are present.

There remains finally the somewhat difficult task of homologizing the opercular elements in Arthrodires and Dipnoans: difficult, because more than one interpretation is open to us, and we cannot be entirely certain as to which plate or plates of the Coccostean skeleton corresponds to the two opercular bones found in typical Dipnoans. It is a well-known fact that the suborbital in Coccosteus is succeeded behind by a small, deep, semi-elliptical plate with free hinder margin, although no such bone has been found in Dinichthys, and in Neoceratodus the corresponding space is filled by cartilage or fibrous tissue. The branchial aperture does not occur in this vicinity in the modern form, but is placed considerably further back. The doubtful element referred to in Coccosteus is lettered "*x*" in Woodward's restoration of that genus, "*j*" in Traquair's, and in Jaekel's it is unmarked. The first-named author suggests that it is "not improbably to be regarded as the operculum;"[1] Traquair interprets it as jugal;[2] Jaekel as quadrato-jugal.[3] Against its interpretation as an operculum it may be argued that the bone in question is of disproportionally small size; is situated relatively too far forwards, where we should expect the side wall of the head to be closed; is unaccompanied by any subjacent element answering to the suboperculum; and has apparently no equivalent amongst other Arthrodires. In Dinichthys, the corresponding space is covered by the posterior portion of the suborbital, which extends as far as the postero-lateral angles of the headshield, and is in close proximity below with the so-called "clavicular." Judging from this fact, and from the conditions observed in Neoceratodus, it seems preferable to regard the bone "*x*" in Coccosteus merely as an intercalary piece which may exist occasionally as a separate ossification, and serves to protect the side of the head. The consequence of this view is that we shall be compelled to search, as Jaekel has done, for the operculum and suboperculum amongst plates forming part of the lateral armoring of the trunk.

According to Jaekel's idea (*loc. cit.*, p. 109), the opercular elements

[1] Woodward. A. S. Catalogue fossil fishes British Museum, 1891, pt. 2, p. 280, Fig. 44.

[2] Traquair, R. H. On the structure of Coccosteus decipiens Agassiz. Ann. Mag. Nat. Hist., 1890, ser. 6, 5, p. 127, Plate 10, Figs. 1, 2.

[3] Jaekel, O. Ueber Coccosteus und die Beurtheilung der Placodermen. Sitz. Gesell. Nat. Freunde, 1902, p. 108 (restoration, p. 107).

of Coccosteus are to be sought in the plates which Traquair has named antero-lateral and antero-dorso-lateral. This identification we are prepared to accept in part only. The antero-dorso-lateral, we believe, must be excluded from association with opercular elements, on account of differences in form and relative position; because it is articulated with the headshield; and also because its dorsal and ventral margins are overlapped by contiguous plates. Besides, it is traversed by sensory canals in a manner quite unusual for the operculum.

Otherwise is the case with the antero-lateral, or "clavicular," as the corresponding plate is called in Dinichthys. It has a somewhat similar configuration, is of about the some relative size, and occupies the same relative position both in these genera and in Neoceratodus. Its upper portion overlaps the postero-lateral margin of the headshield for a short distance behind the prominent postero-lateral angles, and its lower front portion extends forward so as to continue the contour of the lower jaw with scarcely appreciable interruption. Another important fact to be observed is that this plate, both in Coccosteus and Dinichthys, occurs in association with a small rod-shaped or spiniform piece, lying immediately underneath, which is highly suggestive of the suboperculum in typical Dipnoans. First observed in Brachydirus, where for lack of a more appropriate name it was called "Ruderorgan" by von Koenen, this bone was afterwards detected in two species of Coccosteus by Traquair, who named it "lateral spine," and compared it with the fixed spinous appendage of Phlyctaenaspis and Acanthaspis.[1] We misdoubt greatly whether the implied homology exists. Rather it seems to us that the fixed spinous appendage of the two last-named genera should be regarded as an elongated process of the ventral system of plates, whereas in Coccosteus, Brachydirus, and Dinichthys the lateral spine (= "pectoral fin-spine" of Newberry) is free, and meets all theoretical requirements for a suboperculum. There is reason to believe, therefore, that the antero-lateral and "lateral spine" of Coccosteans correspond, respectively, to the operculum and suboperculum of typical Dipnoans; and the branchial aperture may be supposed to have been placed in the prominent sinus formed by the lateral armoring of the trunk immediately behind these plates. This is also the region where we should expect pectoral fins to have been attached, were such structures devel-

[1] Traquair, R. H. Notes on the Devonian fishes of Campbelltown, etc. Geol. Mag., 1893, ser. 3, **10**, p. 149. Notes on Palaeozoic fishes. Ann. Mag. Nat. Hist., 1894, ser. 6, **14**, p. 370. These are apparently the references alluded to by Jaekel in the postscript to his paper on Coccosteus, *loc. cit.*, p. 115.

oped. It is at least where traces of them should be looked for amongst the most primitive genera.

Autostyly. — No Arthrodire thus far discovered can be definitely proved to have been autostylic. This type of cranial structure is to be inferred, however, (1) from concurrent testimony of other characters pointing to Dipnoan relationships; (2) from the remarkable similarity of the jaw-parts to those of modern Dipneusti; (3) from the absence of any ossification which can be interpreted as hyomandibular, even in the most exquisitely preserved skeletons; (4) from the occurrence of articular cartilage in natural association with the lower jaw of Dinomylostoma; and (5) from the position and appearance of a pair of well-marked fossae on the under side of the head in Macropetalichthys, described by Cope as "an articular glenoid cavity, possibly for the condyle of a mandible."[1] Regarding these latter structures, it need only be remarked that Cope's interpretation is materially strengthened by the resemblance between the fossae and certain facets for articulation with the mandible as seen in the quadrate element of Dipterus;[2] a resemblance which serves, by the way, to emphasize the close approach made by this extremely generalized form to Ctenodipterine conditions. Macropetalichthys offers in many ways a fair presentment of an ancestral, synthetic type.

We may conclude this phase of the subject by calling to mind the caution that Dollo and Bridge have urged against attributing too great significance to the occurrence of autostyly amongst fishes. Reasons have been given by these authors for believing that the nature of the suspensorium must not necessarily be regarded as an indication of genetic affinity, and that autostyly is a purely adaptive modification. Thus, it is held by Bridge that the autostylic condition of the skull "may occur independently in diverse groups of Fishes wherever any advantage is to be gained from the fixation by fusion to the skull of the primitive elements of the upper jaw (palato-quadrate cartilage) for the purpose of providing the needful support for a massive and peculiar dentition, or even, as I have suggested above, for a system of labial cartilages in a suctorial mouth."[3] In the opinion of the writer last quoted, it is imma-

1 Cope, E. D. On the characters of some Palaeozoic fishes. Proc. U. S. Nat. Mus., 1891, **14**, p. 453.

2 Traquair, R. H. On the genera Dipterus, etc. Ann. Mag. Nat. Hist., 1878, ser. 5, **2**, p. 5, Plate 3, Figs. 1–4.

3 Bridge, T. W. On the morphology of the skull in the Paraguayan Lepidosiren. Trans. Zool. Soc. London, 1898, **14**, p. 372.

terial whether Arthrodires were autostylic or hyostylic; the ultimate proof of their Dipnoan relationships must rest on other characters than these. Fürbringer's commentary on the views just stated will be found on page 501 of his monograph on the skeleton of Dipnoans to which we have several times referred.

Body characters indicating Dipnoan affinities of Arthrodires. — It is safe to affirm that the main outlines of the skeletal structure of Arthrodires, except only for the development of dermal armor, agrees intimately with those of recent Dipnoans. A certain amount of resemblance might be explained as due to parallelism; but no such theory can account for the striking coincidence in structural plan to be observed throughout all parts of the body. It would be absurd to suppose that one group of organisms, such as Arthrodires, coincides fortuitously with the principal features of another group, — as, for example, Ceratodonts — without the two being nearly related. When it is realized that essential unity of structural type pervades not only the cranium but the entire skeleton of the groups mentioned, the obvious inference to be drawn is that they share a common origin. This is a legitimate, and, indeed, unavoidable deduction. We might even proceed further, and, if one cared to speculate as to the ultimate origin of Dipnoans, a number of characters would be found suggesting descent from Pleuracanthus-like sharks.[1]

The body characters in which Arthrodires may be claimed chiefly to resemble modern Dipnoans are as follows: (1) a persistent notochord; (2) diphycercal tail; (3) segmental correspondence between the skeletal supports of the soft dorsal fin and the vertebral axis, to the extent that the two sets of interspinous bones are articulated with each other and also with the neurapophyses by expanded extremities, there being an equal number of interneurals and neural spines; (4) punctate dermal plates; and (5) — although this last point requires further confirmation — an apparently similar conformation of the pelvic arch.

On the other hand, the following points of difference are to be noted between Arthrodires and modern lung-fishes: (1) encasement of the anterior portion of the trunk in dermal armor; (2) apparent atrophy of the anal and pectoral fins; and (3) shortening of the dorsal into a single, abbreviate, membranous fin situated in the middle of the back. None of these characters, however, are of fundamental importance,

[1] *Inter alia*, the notochordal axis, diphycercal tail, biserial pectoral fins, basipterygial pelvic girdle, and, most singular of all, the Dipnoan-like arrangement of dermal bones roofing the head.

representing as they do merely the specialization peculiar to Arthrodires. Their aggregate is of no greater taxonomic importance than the sum-total of differences between Ctenodipterines and Sirenoids. Quite the contrary, for the distinctions between Arthrodires and Ceratodonts are on the whole less trenchant than between the latter and Ctenodipterines. The one constant character in which all Ctenodipterines differ from existing Dipnoans is, as pointed out by Bridge, the multiplicity and almost Acipenseroid arrangement of their cranial roofing bones. Oddly enough, it is precisely this feature wherein a constant difference exists between the groups named, that a constant resemblance is to be noted between modern lung-fishes and Arthrodires. The cranial pattern of the two latter types is essentially identical, but anomalous as compared with all other vertebrates.

The differences between the Ctenodipterine and Sirenoid orders of *Dipneusti* have been tabulated by several writers, among whom it will be sufficient to mention Bridge and Fürbringer, in their monographs already several times quoted. By extending the range of comparison far enough to include Arthrodires as well, it will be observed that the two extinct orders (*i. e.*, Ctenodipterines and Arthrodires) agree with modern Dipnoans and differ from all other fishes in possessing the following combination of cranial characters [1]: —

1. The presence of characteristic tritoral or trenchant dental plates in upper and lower jaws, the former supported by palato-pterygoid elements, usually ossified, and the mandibular by the greatly developed splenial bones of the lower jaw.

2. The absence of maxillae and premaxillae in the upper, and of a true dentary bone in the lower jaw.

3. The presence of only two opercular bones, an operculum and an interoperculum, and the absence of a distinct preopercular element.

4. Complete and typical autostyly in at least the two more commonly recognized orders, and presumably in the Arthrodiran as well.

Structural Characters of Mylostomids.

Mylostoma was established by J. S. Newberry in 1883 upon the evidence of dissociated parts of the dentition, no specimen being known to him in which the dental elements were preserved in natural position or accompanied by other portions of the skeleton. Under these cir-

[1] See the remarks on this subject by Professor Bridge, in his Monograph on Lepidosiren, page 365.

cumstances it is not to be wondered that his descriptions were imperfect, and his ideas as to the systematic position of the genus confused. Newberry's original suggestion was that Mylostoma should be referred "to the group which includes Dipterus, Palædaphus, Ctenodus, and Ceratodus."[1] Six years later he included the genus under the head of "Placoderms," considering it to be an extremely specialized "member of the family of the Dinichthidae;"[2] yet on another page of the same work these fishes were defined as "Dipterine Ganoids of large size," and the points of resemblance between them and Ctenodipterines were considered "sufficient to justify the inference that they were all related."[3]

Without attempting a theoretical reconstruction of the Mylostomid type of dentition, Newberry was nevertheless convinced that it was extremely complicated. The beveled edges and other appearances of certain specimens were interpreted by him as indicating co-adaptation with contiguous elements, whence it followed that several pairs of dental plates must have been present in the lower jaw, and the upper dentition was supposed to be in the form of a "tesselated pavement consisting of many pairs of plates."[4] The author's own words with reference to the latter point are as follows: —

"The dental plates of the upper jaw form several pairs, of which the central and largest are rudely triangular in outline, with a flattened or concave triturating surface, bearing, as do some of the inferior teeth, evidences of wear. The surface of attachment to the cranium of these dental plates is flat or concave and somewhat rough, from the coarse cellular tissue of the bone; the sides are straight or beveled, apparently for co-adaptation, and by this character favor the conclusion that the dentition consisted of many pairs of plates, constituting a tesselated pavement; the crowns of the teeth below being convex, those above concave."

It was reserved for Dr. Bashford Dean[5] in 1893, and more completely in 1901, to disclose the essential characters of Mylostoma, and to demonstrate its close relation with Dinichthys, as the result of his study of an admirably preserved specimen of *M. variabile* from the Cleveland shale of Ohio. Eventually, one of the counterparts of this

[1] Newberry, J. S. Some interesting remains of fossil fishes, recently discovered. Trans. N. Y. Acad. Sci., 1883, **2**, p. 146.

[2] *Idem.*, Monogr. U. S. Geol. Surv., 1889, **16**, p. 163.

[3] *Ibid.*, pp. 161, 163.

[4] *Ibid.*, p. 165.

[5] Dean, B. On Trachosteus and Mylostoma, Notes on their Structural Characters. Abstract. Trans. N. Y. Acad. Sci., 1893, **12**, p. 70–71. Palæontological Notes: On the Characters of Mylostoma Newberry. Mem. N. Y. Acad. Sci., 1901, **2**, p. 101–109.

specimen was acquired by the Museum of Comparative Zoölogy at Cambridge, the other by the American Museum of Natural History, New York. One will readily appreciate the importance of this example when it is remembered that but one other Mylostomid is known in which nearly the complete dentition occurs in natural association with portions of the headshield and abdominal armor. The second specimen referred to will be found hereinafter described as the type of a distinct genus, Dinomylostoma.

The structural characters of Mylostoma have been worked out with such thoroughness and precision by Dean in his elaborate monograph of 1901, that it would be futile to attempt to supplement his descriptions. Only in a few particulars is a somewhat different reading of the original to be advocated than that which is preferred by him. Thus, the construction which we should place upon the dental elements of the upper jaw is indicated in Fig. E, the evidence for which rests

FIG. *E.* — Upper dentition of *Mylostoma variabile* Newb., from the Cleveland shale of Sheffield, Ohio. × ½.

upon the following considerations: — (1) In no other position is there such accurate fit between upper and lower dental plates when the jaws are closed; (2) it is the only arrangement which accounts at all points

for reciprocal marks of wear; (3) the reconstruction here shown is in harmony with ontogenetic evidence; and (4) the same disposition has been found to hold true also for Dinomylostoma (*vide infra*).

It may be noted further that there does not appear to be any certain trace of the median ventral plates, and in Dean's restoration of the ventral armor one perceives that the antero- and postero-ventro-laterals have been interchanged. The restoration of the headshield and configuration of the dorso-median plate, as shown in Dean's figure 3 must be understood as largely conjectural; and his statement that the orbits are "placed dorsally and somewhat closely together, characters which perhaps might be expected in a fish of ray-like habits," cannot be confirmed. Mylostoma agrees with Coccosteus and Dinichthys, rather than with Homosteus, as regards position of the orbits, and there is no indication that the body was depressed dorso-ventrally in any of these genera.

In Plates 1 and 2 are shown a number of palato-pterygoid plates belonging to *Mylostoma variabile*, some of which are type specimens; and in Plate 3 are represented two of the mandibular dental plates belonging to the same species (Figs. 19, 20), and also the type specimen of *M. terrelli* Newberry (Fig. 21). None of the originals selected for illustration seem to require further comment than will be found in the explanation of the plates. For having generously placed material belonging to the American Museum of Natural History at the writer's disposal, his appreciative thanks are due and here rendered to his friend Dr. Dean, honorary curator of fossil fishes, as well as to his assistant, Mr. L. Hussakof.

Dinomylostoma Eastman.

Arthrodiran fishes exhibiting characters transitional between Mylostoma and Dinichthys. Tritoral palato-pterygoid dental plates adapted for crushing, but the opposing lower dentition very similar to that of Dinichthys, except that the functional margin is thickened into a broad, more or less smooth, and regularly concave grinding surface, contracting in front and elevated into a blunt symphysial beak. Vomerine teeth subtrihedral, slightly prehensile, and of a general Dinichthys-like aspect. Dorso-median with prominent inferior carina terminating in an excavated posterior process; other plates of the abdominal armor resembling those of typical Coccosteans, the external surface covered with fine vermiculating rugæ.

Dinomylostoma beecheri Eastman.

Plate **1**, Figs. 4, 5; Plate **2**, Figs. 13, 14, 16, 17; Plates **4**, **5**.
Amer. Journ. Sci. 1906, ser. 4, **21**, p. 137, Text-Fig. 2.

The specific characters of this form are included under the foregoing generic diagnosis. That which is regarded as the most distinctive

feature, and serves at the same time to emphasize the transitional nature of this genus, consists in the beak-like termination of the mandibles in front, together with their deeply concave and approximately even oral margin. The general contour of the mandible, apart from lateral thickening of the oral margin, is Dinichthys-like; but precisely this thickened condition imparts to it a certain Palaeomylus-like aspect. As regards functional adaptation, therefore, Dinichthys and Dinomylostoma are related to each other in much the same way as are Rhynchodus and Palaeomylus amongst Chimaeroids. Approach to Dinichthyid conditions is to be noted also in the slightly prehensile form of the vomerine teeth of Dinomylostoma. These teeth, if found in the detached condition, might readily be mistaken for the so-called "premaxillaries" of Dinichthys. On the other hand, the palato-pterygoid dental plates are typically Mylostomid. If they in their turn were known to us only in the detached condition, they would be unhesitatingly assigned to the genus Mylostoma. One perceives, accordingly, that the new form acquaints us with an interesting intermediate stage of modification between two well-marked types of Arthrodires, of which the Mylostomid is clearly the more primitive.

Our knowledge of the form *sub judice* is derived from a unique example, the history of which is as follows: Collected in the year 1868 from a shaly outcrop of Portage beds upon the farm of John Pierce, near Mt. Morris, New York, it was acquired by the late Prof. O. C. Marsh, and by him deposited in the Yale Museum. Here it remained for many years stored away and apparently forgotten. The writer's attention was first called to it by his lamented friend Professor Beecher, shortly before the unfortunate loss to science of the latter. Through the kindness of his successor, Prof. Charles Schuchert, the specimen was committed to the present writer for further preparation, study, and description, and for this privilege cordial thanks are here offered. At Professor Schuchert's suggestion, also, the specific title is inscribed to the memory of his distinguished friend and predecessor.

The type specimen upon which the species is founded presents the following parts for examination: nearly the complete dentition; fragmentary portions of the headshield; a part of the left suborbital shown in Fig. F; the dorso-median, substantially perfect; and two of the ventro-lateral plates, one complete, the other in impression.

Naturally, chief interest is engaged by the dentition. Both mandibles are preserved, and are shown from the external and internal aspects in Plates 4 and 5 respectively. The anterior margin rises into a

rather obtuse symphysial beak, but slightly elevated above the broad, flat, deeply excavated functional surface. The latter displays a single inconspicuous tubercle close to the external margin, situated about midway its length, and its posterior termination is marked by a still larger tubercle, rather elongate, and placed externally like the first. This posterior prominence fits snugly against the single large rounded boss of the opposing palato-pterygoid dental plate, the adjustment being such as to orient the hinder pair of upper dental plates with absolute precision. It is fortunate that we have this topographic control, since it serves as a check upon any theoretical reconstructions of the upper dental plates of Mylostoma that might be attempted.

The lower dental plate proper, or that portion of the mandible which

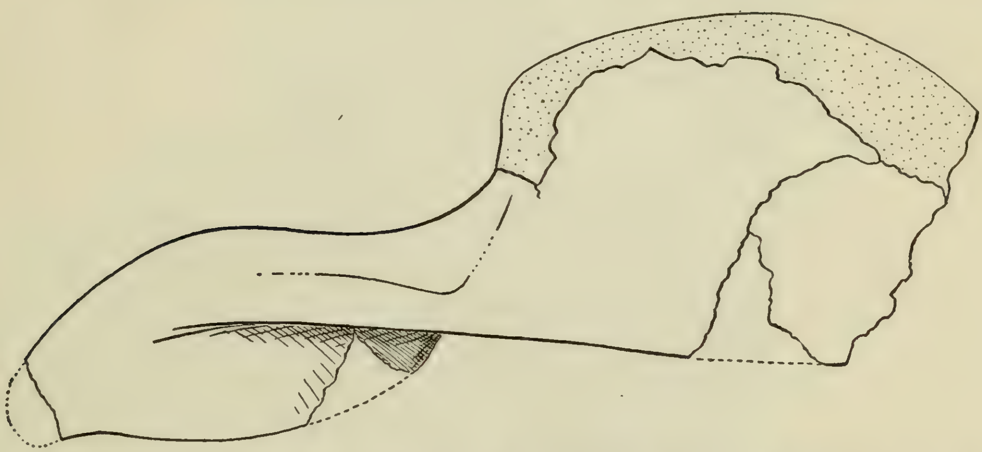


Fig. *F.* — Portion of left suborbital of *Dinomylostoma beecheri* Eastman, from the Portage of Mt. Morris, N. Y. External aspect, × ½.

corresponds to the lower dental plate in related forms, is so intimately united with the supporting splenial that the two might be said, so far as appearances go, to form an integral piece. The same, however, might be said of modern Dipneumon genera, and if one is really in doubt whether two separate entities are concerned, that doubt is dispelled by the most cursory examination of the mandible in Mylostoma, where we find a veritable pharos for indicating Dipnoan affinities. The splenial of Dinomylostoma is developed as a long, slender posteriorly rounded shaft, much resembling that of Dinichthys, but relatively a little deeper. A fact of great interest is that both of these elements, the right and the left, are preserved in natural association with the articular cartilage, and this, although considerably compressed by mechanical processes, is seen to form a hinge for attachment with the suspensorial cartilage of

the cranium (Fig. G). The cartilage extends along the outer side only, as we should expect it to, of the splenial, for a distance equalling at least the depth of the bone it is attached to. Originally it may have extended for an even greater distance anteriorly, but in the actual condition of the specimen this cannot be determined positively. The usual groove which is presumed to have been occupied by a remnant of

FIG. *G.* — *Dinomylostoma beecheri* Eastman. Calcified articular cartilage belonging to type specimen, detached from outer face of right mandibular ramus; found in position corresponding to that shown in Plate 4, Fig. 23.

Meckel's cartilage is present along the inferior margin, its direction and position being as in Dinichthys and other Coccosteans.

Both of the vomerine teeth are present, and are readily identifiable as such on account of their strong resemblance to the corresponding elements of Dinichthys. Their extreme tips are broken away, but it is evident from the cross-section of the fractured part, as seen from the oral surface (Plate 1, Figs. 4, 5; Plate 2, Figs. 13, 14), that they must have been prehensile to about the same degree as the symphysial beaks

of the lower jaw, against which they closed. Their posterior face is smooth and slightly concave, as if for co-adaptation with the front margin of the anterior pair of palato-pterygoid dental plates. These latter are unfortunately missing in the type specimen, but as their allotted space is accurately demarcated on all sides, it is easy to restore their outlines. Thus, their posterior face must have abutted directly against the hinder pair of palato-pterygoids, and their outer face have been conformable to the external margin of the opposing lower dental plates; this much, at least, is certain. The inner face we should expect to be linear and elongate, as in Mylostoma, in consequence of the close juxtaposition of the two forward plates along the median line. That the corresponding plates of Mylostoma were arranged in the manner indicated is too evident to require demonstration; it must be apparent to any one who has ever handled the actual specimens, and applied their oral surfaces against the lower dentition.

The hinder pair of palato-pterygoid dental plates is excellently preserved, as will be seen from the illustrations given in Plate 2, Figures 16 and 17. These plates are elongate, of irregularly cruciform outline, moderately thick, and develop on their oral surface a single, large, rounded, centrally placed tubercle, which plays into a corresponding depression of the lower dentition in the manner already described. A peculiar feature of the plates in question is that the sinus which occurs in about the middle of the posterior face shows vertical flutings and is otherwise differentiated from the adjacent lateral edge of the plate. It is difficult to imagine what purpose this excavation with fluted walls could have served, unless it enclosed a passageway of some sort. The opening is much larger than is needful to conduct nerves or blood-vessels; and besides, it communicates directly with the mouth cavity, as is evident from the fact that the flutings are conterminous with both the upper and lower surfaces of the plate. Now the only openings of corresponding size and position that we are acquainted with in the palate of any other fishes are the *posterior nares*, which are found only in Dipnoans; and the inference is by no means remote that we have to do with these very structures in Dinomylostoma.

Figure H is intended to show the relative positions of upper and lower dental plates as determined for this genus, without, however, including the anterior pair of palato-pterygoid elements. The vomerine teeth are shown from their oral aspect, and in their natural position with respect to each other, but removed further forward from where they belong for the purpose of displaying the contour of the mandibular

element. We will conclude our description of the new form by presenting measurements of the more important elements as follows:

The vomerine teeth have a length along their narrow longitudinal margin of 3 cm. Their width across the posterior face in a transverse direction is 3.5 cm., and obliquely across the external face it is 4 cm. The posterior palato-pterygoid dental plates have major and minor axes of

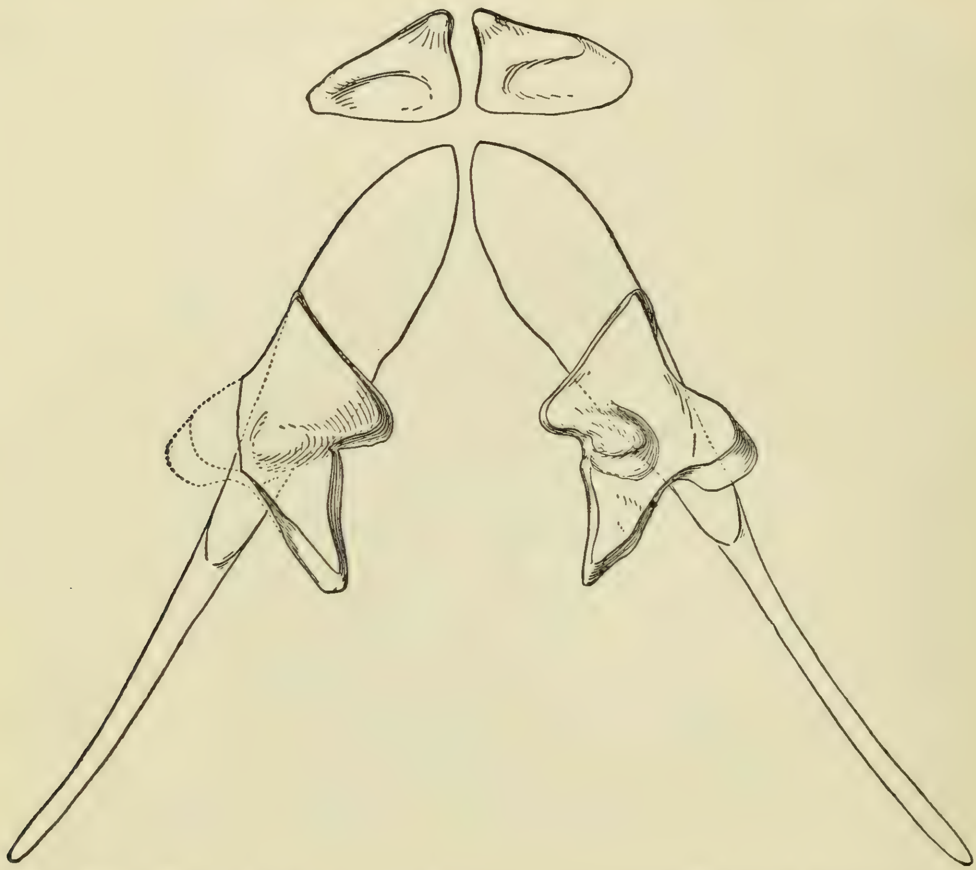


FIG. *H.* — Diagram showing contour of oral margin of mandibular and posterior palato-pterygoid dental plates of *Dinomylostoma beecheri* Eastman, in front of which are shown the upturned vomerine pair, all drawn to the same scale, and the members of each pair placed in natural position with respect to each other. × ½.

6.8 and 5 cm. respectively, and a thickness of about 2 cm. except in the central portion where the dome-shaped tubercle increases it to a total of 2.5 cm. The extreme length of the mandible falls a trifle short of 20 cm., that of the functional margin is about 8 cm., and the maximum width of the latter is 2.3 cm. The dorso-median plate, indistinguishable in form from that of *Dinichthys intermedius*, and with well developed posterior process, is estimated to have had a total width of 18 cm. It is unfortu-

nately not preserved for its entire length, but would seem to have been at least 15.5 cm. long, exclusive of its terminal process. The dimensions of the ventro-lateral plates cannot be determined with any great nicety, but although exhibiting about the same proportions, they are fully one-fifth smaller than the corresponding elements in the unique example of Mylostoma figured by Dean.

EXPLANATION OF PLATES.

PLATE 1.

Upper Dentition of Mylostomids.

All specimens are shown of the natural size. Those of Mylostoma are from the Cleveland shale (Upper Devonian) of Sheffield, Ohio.

Fig. 1. Right anterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. Type specimen figured in Plate 13, Fig. 4 of Newberry's Monograph, 1889. Original preserved in American Museum of Natural History (Cat. No. 43 G).

Fig. 2. Left anterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. Type specimen figured in Plate 15, Fig. 4 of Newberry's Monograph, 1889. Original preserved in the Museum of Comparative Zoölogy (Cat. No. 1435).

Fig. 3. Left anterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. Type specimen figured in Plate 13, Fig. 3 of Newberry's Monograph, 1889. Original preserved in American Museum of Natural History (Cat. No. 42 G).

Figs. 4, 5. Right and left vomerine teeth of *Dinomylostoma beecheri* Eastman, seen from the anterior external aspect. Type in Peabody Museum, Yale University. From the Portage beds of Mt. Morris, N. Y.

Fig. 6. Left posterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. This plate belongs to the small, probably immature, individual described by Dean in the Memoirs N. Y. Acad. Sci. for 1901. Original preserved in the American Museum of Natural History; counterpart in the Museum of Comparative Zoölogy.

Fig. 7. Vomerine tooth of *Mylostoma variabile* Newb. Original in Museum of Comparative Zoölogy (Cat. No. 1439).

Fig. 8. Right posterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. Original preserved in American Museum of Natural History (Cat. No. 3591).

Fig. 9. Left posterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. Original preserved in the Museum of Comparative Zoölogy (Cat. No. 1437).

PLATE 2.

Upper Dentition of Mylostomids.

Fig. 10. Left posterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. Original preserved in American Museum of Natural History (Cat. No. 44 G).

Fig. 11. Same as preceding. Original preserved in the Museum of Comparative Zoölogy (Cat. No. 1438).

Fig. 12. Left anterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. Original preserved in American Museum of Natural History (Cat. No. 3290).

Figs. 13, 14. Vomerine teeth of *Dinomylostoma beecheri* Eastman, seen from the posterior aspect, and showing gently concave surface for co-adaptation with the anterior pair of palato-pterygoid elements. Originals in Peabody Museum, Yale University.

Fig. 15. Right posterior palato-pterygoid dental plate of *Mylostoma variabile* Newb. turned with the posterior margin uppermost, or in opposite position from Figs. 8, 9, 16 and 17. Type specimen figured in Plate 15, Fig. 5, of Newberry's Monograph, 1889. Original preserved in the Museum of Comparative Zoölogy (Cat. No. 1436).

Figs. 16, 17. Posterior pair of palato-pterygoid dental plates of *Dinomylostoma beecheri* Eastman, to be compared with Figs. 8 and 9 of Plate 1.

Fig. 18. Vomerine tooth of a small undetermined Coccostean, possibly of Dinichthys, shown for purpose of comparison with the vomerine teeth of Mylostoma.

All specimens are shown of the natural size, and with the exception of Figs. 13 ,14, 16, and 17 are from the Cleveland shale (Upper Devonian) of Sheffield, Ohio.


10
12
13
14
18

PLATE 3.

Lower Dentition of Mylostoma.

FIGS. 19, 20. Oral aspect of lower dental plates belonging to the left ramus of the mandible in *Mylostoma variabile* Newb. Both specimens are preserved in the Museum of Comparative Zoölogy (Cat. Nos. 1429, 1431) and have been previously figured in Plate 15 of Newberry's Monograph. Natural size.

FIG. 21. Oral aspect of left mandibular ramus of *Mylostoma terrelli* Newb. This is the type and only known example; it is preserved in the Museum of Comparative Zoölogy (Cat. No. 1430). $\times \frac{3}{4}$.

19 20 21

PLATE 4.

Lower Dentition of Dinomylostoma.

FIGS. 22, 23. External aspect of right and left mandibles of *Dinomylostoma beecheri* Eastman. Portage beds; Mt. Morris, New York. Original in the Peabody Museum of Yale University. Natural size.

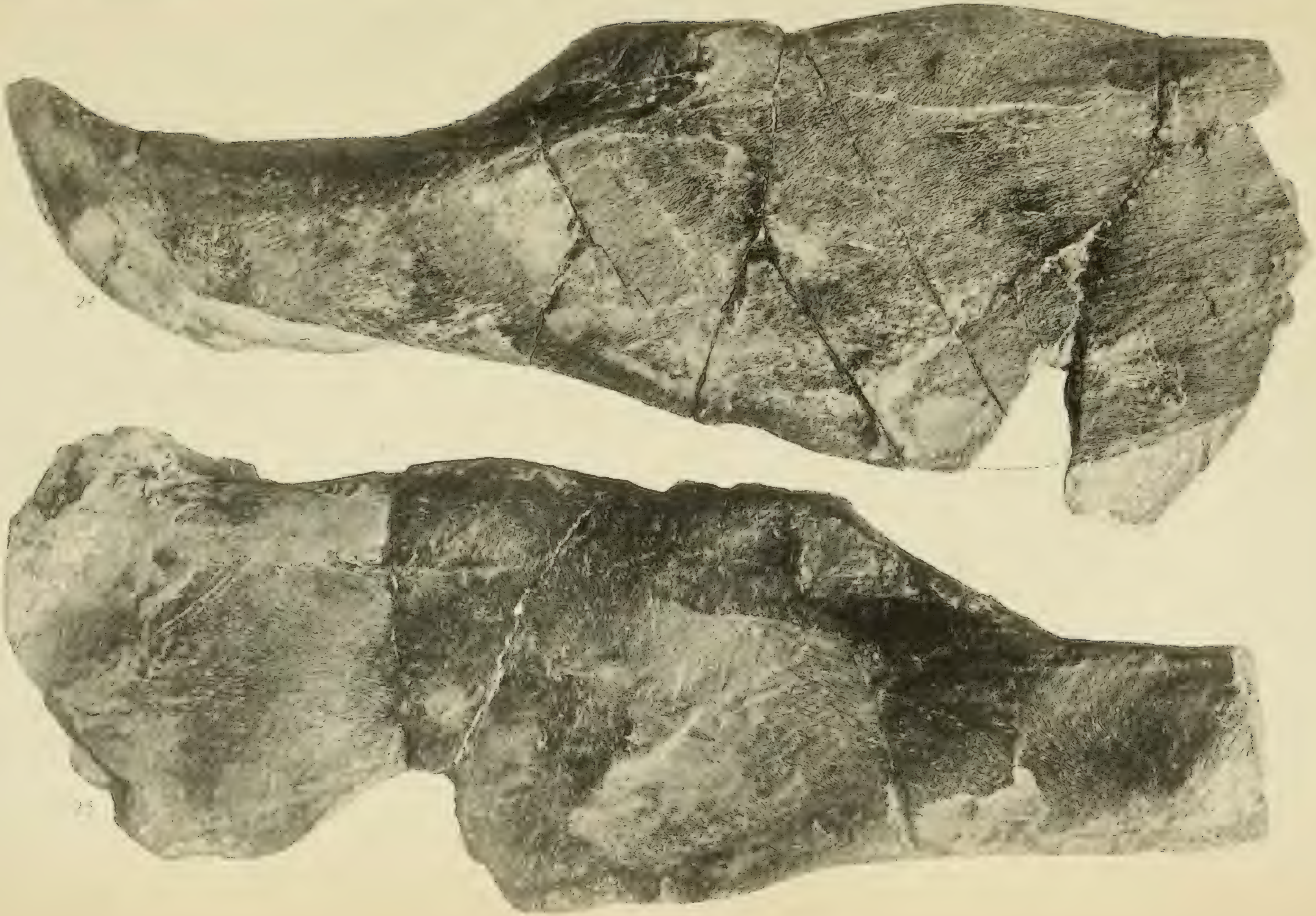
Eastman. — Mylostoma.

Plate 1.

PLATE 5.

Lower Dentition of Dinomylostoma.

Figs. 24, 25. Inner aspect of the mandibular rami belonging to the type specimen of *Dinomylostoma beecheri* Eastman. Natural size.



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FOSSIL HYMENOPTERA FROM FLORISSANT, COLORADO.

By T. D. A. Cockerell.

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No. 2.—*Fossil Hymenoptera from Florissant, Colorado.*

By T. D. A. Cockerell

The Tertiary shales of Florissant, Colorado, have been made famous through the writings of Lesquereux and Scudder, wherein are described hundreds of species of plants and insects preserved in fine volcanic ash and sand. The vast multitudes of individuals and species, and the wonderful state of their preservation, render the locality perhaps the richest of its kind in the world, and afford us as good an opportunity as could be looked for to reconstruct the fauna and flora of a remote age. Just what age this is, is a matter in dispute; but for various reasons, which I give in a paper to be issued in the University of Colorado Studies, I think it is almost surely Miocene.

Unfortunately, Mr. Scudder has not been able to finish the investigation of the materials he secured at Florissant. In his work on *Tertiary Insects* (1890) he indicated briefly the great wealth of undescribed species. Since then he has published some miscellaneous species (Bull. **93**, U. S. Geol. Surv., 1892), the Rhynchophorous Coleoptera (Monog. U. S. Geol. Surv., 1893, **21**), the Adephagous and Clavicorn Coleoptera (Monog. U. S. Geol. Surv., 1900, **40**), and the Tipulidae (Proc. Amer. Philos. Soc., 1894, **32**). The great work accomplished by Mr. Scudder can in some measure be understood by one who has learned the difficulties of this kind of investigation; the eye-strain involved in determining minute and often nearly obliterated features, and the wide knowledge and good judgment necessary in order to classify specimens which only exhibit part of the characters commonly used as diagnostic. It is not to be expected that another such master of palaeoentomology will appear to take up the work; but the valuable materials must not be neglected, and we may hope that with the aid of several workers they will all be made known.

The present contribution deals with the bees and wasps, and one species of Stephanidae, kindly entrusted to me by the Museum of Comparative Zoölogy. In addition to the species described, I have examined more imperfect specimens of perhaps as many others; but it has seemed best to publish only those which could be classified with

some certainty, and adequately diagnosed. If the imperfect specimens just mentioned had been all the Hymenoptera found at Florissant, it would have seemed worth while to give them more careful scrutiny, and to describe a number as well as possible. No doubt, by very careful and prolonged comparisons, such portions of the venation as could be determined would be found in many cases to reveal probable or practically certain affinities; but the work would be arduous in the extreme, and would test one's skill to the utmost. As it is, the numerous well-preserved specimens give us an excellent idea of the fauna, and the determination of the poorer materials may be at least postponed without any serious injury to science.

In numerous cases, owing to the wings being folded, or one beneath another, the venation looks at first sight abnormal, and will appear to disagree with the descriptions offered. The future student of these insects should therefore not conclude too hastily that the descriptions are inaccurate.

In general terms, it may be said that the Florissant Hymenoptera do not differ greatly from their modern representatives. While some of the extinct genera are apparently more primitive than the *dominant* genera of the same groups to-day, they are scarcely more so than certain genera which still exist in the modern fauna. Thus, among the Scoliids, we naturally assume that those forms with regular venation, like that of many other wasps, are more primitive — at least in respect to this character — than those with broken or irregular cells. The two fossil genera of this group are therefore less specialized in venation than the common species of to-day, but they are in the same general stage of development as the rare American genus Engycystis, and the Australian Austratiphia. Thus, if it were possible to restore the Florissant Hymenoptera to their original state, and send them to some entomologist as coming from an out of the way region, he would see in them nothing transcending the possibilities of the modern world.

It must further be said, that the types represented do not suggest tropical or subtropical conditions; they accord well with the vegetation in indicating a climate like that of the austral zones of the temperate region. The bees are principally of genera found flying in Colorado to-day, and there is no indication of the types especially characteristic of Mexico. Both among the bees and the wasps, the element which we regard as of neotropical origin is conspicuously absent. It is only just to remark, with regard to the bees especially, that the generic identity assumed from the parts preserved might in some cases be belied, could we examine the

mouth-parts, etc. The evolution of the bees has gone on principally in the development of the mouth-structures, the venation remaining nearly as in the fossorial wasps, or at any rate not undergoing any radical changes. Hence it may be that if we could see the tongue, palpi, etc., of the Florissant species of Halictus, Andrena, Anthidium, etc., we should be compelled to remove them from those genera; but the agreement of the wings and general appearance is such that I feel as confident of the generic determinations as is possible under the circumstances.

The families represented are exactly those dominant to-day in North America, and the absence of certain groups must no doubt be regarded as accidental.

One would infer from the evidence afforded by the Florissant Hymenoptera, that the genera of this group are more persistent in time than the genera of Mammalia, but less so than those of flowering plants, especially trees. The same conclusions might be reached independently by a study of geographical distribution, at least so far as they relate to mammals and Hymenoptera. No doubt the genera of Hymenoptera are more widespread than some other groups of organisms which may possess greater antiquity, owing to the ready locomotion of the former.

Unfortunately, we have no series of mammals known to be of the same age as the Florissant shales. The White River beds, which Matthew (1899) calls Oligocene, have produced in Colorado some 63 species of mammals, all referred to extinct genera except a few pertaining to Didelphys and Sciurus. These animals, very differently from the Florissant Hymenoptera, if produced alive would excite the greatest amazement. Species of Titanotheriidae, Elotheriidae, Hyaenodontidae, Rhinocerotidae, Camelidae, Oreodontidae, etc., would cause bewilderment to a zoölogist to-day. Even those pertaining to families still inhabiting the earth would for the most part look quite strange to us, being of extinct genera.

The Loup Fork beds, referred to the Upper Miocene, have produced in Colorado about 28 species of mammals, but even these are nearly all of extinct genera, though only two, possibly three, of the families are extinct. We note the arrival of the Elephantidae, and the great abundance and variety of Equidae. As the Florissant shales are certainly not *later* than the Loup Fork, but doubtless earlier, the opinion that the families and genera of aculeate Hymenoptera are much more conservative than those of Mammalia seems justified. The same facts lead us to believe that the differences noted by Scudder between the insects of the Green River series and Florissant surely indicate a considerable difference

in time; and since the Florissant beds must for a variety of reasons be held to be the later of the two, the probability that they are Miocene is augmented.

APOIDEA.

TABLE OF SPECIES.

Three submarginal cells 1
Two submarginal cells 5

1. Basal nervure strongly curved; marginal cell ending in a point on costa; insect small, about 6½ mm. long, anterior wing somewhat over 4 mm. *Halictus florissantellus.*
   Still smaller; length about 4½ mm., intense black *Halictus scudderiellus.*
   Basal nervure not, or not strongly, curved; larger, anterior wing over 5 mm. long 2
2. Second s. m. receiving first r. n. *before* the middle; anterior wing about 8 mm. long . . . . *Calyptapis florissantensis.*
   Second s. m. receiving first r. n. *beyond* the middle, or at apex; anterior wing less than 7 mm. long 3
3. Point of marginal cell a short distance from costa; second r. n. bent near upper end; first s. m. shorter than second or third on cubital nervure *Lithandrena saxorum.*
   Point of marginal cell a short distance from costa; second r. n. not bent near upper end; size small . . . . *Ceratina disrupta.*
   Point of marginal cell on costa; second r. n. not bent near upper end . . 4
4. Abdomen normal; second s. m. just three times as broad below as above *Andrena sepulta.*
   Abdomen clavate; second s. m. narrower, not nearly three times as broad below as above . . . . *Andrena* (?) *clavula.*
5. Stigma small; insect broad and robust 6
   Stigma fairly or quite large; insect smaller, or less robust 8
6. Abdomen subglobose, without visible markings; second r. n. passing well (about 120 μ) beyond apex of second s. m.; breadth of marginal cell about 630 μ . . . . *Dianthidium tertiarium.*
   Abdomen longer, banded 7
7. Wings strongly infuscated; marginal cell about 720 μ broad *Anthidium scudderi.*
   Wings clear; marginal cell about 570 μ broad . . . . *Anthidium exhumatum.*
8. T. m. with the lower end most apicad, so that it forms an angle with b. n.; eyes prominent . . . . *Libellulapis antiquorum.*
   T. m. with the lower end most basad so that it is in line with lower end of b. n. 9
9. Small, length slightly over 6 mm.; abdomen dark brown; width of marginal cell 255 μ . . . . *Heriades halictinus.*
   Larger, length 8 mm. or over; width of marginal cell 300 μ 10
10. Abdomen light reddish brown; head smaller . . . . . *Heriades laminarum.*
    Abdomen banded; head larger . . . . *Heriades bowditchi.*

The following abbreviations are used: b. n. = basal nervure; s. m. = submarginal cell; r. n. = recurrent nervure; t. m. = transverso-medial nervure; t. c. = transverso-cubital nervure. In the wing, breadth always means in the direction of the short axis in the case of the marginal cell and stigma.

CERATINIDAE.

Ceratina disrupta, sp. nov.

Black; probable length about 8 mm., or perhaps less; anterior wing about or not quite 6 mm., dusky, especially in marginal cell and beyond; head separated a short distance from body in type and seen in side view, about 2175 μ long and 1050 from back to front, with the broadly rounded cheeks and general appearance of Ceratina; stigma well-developed, its width about 150 (this and all following measurements in μ), its margin bordering marginal cell about 300; marginal cell 1350 long, 370 wide, ending in a point a little away from costa; first s. m. 800 long, its length on cubital nervure 525; second s. m. much narrowed above its length on marginal 200, on cubital nervure 600; third s. m. 300 long on marginal, nearly 600 on cubital; lower section of b. n. (bordering first discoidal) gently, not strongly, curved, about 675 long; length of first discoidal 1500; first r. n. entering second s. m. beyond middle; second r. n. entering third s. m. 150 from its end, the upper end of the nervure not bent.

Type. — No. 2001, Mus. Comp. Zoöl. Florissant, Col. (No. 9355, S. H. Scudder Coll.).

MEGACHILIDAE.

Anthidium Fabricius.

The species of *Anthidium* differ among themselves in the details of the venation, as shown in the following table:

First r. n. meeting first t. c., or passing a very short distance beyond it.
A. oblongatum Latr. (Europe).
A. bernardinum Ckll. (So. Calif.).
A. illustre Cress. (Western U. S.).

First r. n. passing a fair or long distance beyond first t. c. 1

1. B. n. meeting t. m.; t. m. of hind wing only moderately oblique
A. steloides Spin. (Chile).

B. n. passing basad of t. m. (sometimes very slightly); t. m. of hind wing very oblique 2

2. Basal angle of first s. m. about as acute as angle formed by basal and subcostal nervures . . . . *A. laterale* Latr. (Palaearctic).

Basal angle of first s. m. obviously more obtuse than angle formed by basal and subcostal nervures . . . . *A. emarginatum* Say (Colorado, etc.).
A. conspicuum Cress. (Colorado, etc.).
A. scudderi, sp. nov. (Florissant).
A. exhumatum, sp. nov. (Florissant).

It thus appears that so far as the venation shows, the Florissant species are nearest to some of those flying in Colorado at the present day. In the following descriptions, those characters are italicized which may especially be relied upon for the separation of the fossil species.

Anthidium scudderi, sp. nov.

Robust, probably about 15 mm. long (the end of the abdomen is lacking); width of thorax about 5 mm. (probably increased by flattening), of head about $4\frac{1}{2}$; general appearance normal; head and thorax black, with faintly indicated light markings; apparently the clypeus was light, and a large patch on vertex, and a pair of longitudinal subdorsal stripes on anterior part of thorax (mesothorax), but these markings, vaguely indicated by reddish color, may not truly represent the tegumentary colors; mandibles apparently short and heavy; antennae and legs not visible; abdomen broad, very pale reddish, *with the hind margins of the segments infuscated*, the darkening strongest on the actual margin, and gradually fading anteriorly, the dark band occupying about a third of the visible part of the segment (much less on the first); on the second to fourth segments are rather poorly indicated dark marks in the subbasal region in the middle line, and on each extreme lateral margin, apparently indicating a subbasal band very broadly interrupted in the subdorsal region; it is perhaps probable that the abdomen was in life yellow marked with ferruginous; the apparent pattern is not quite like that of any modern species before me, but it is not difficult to see how it might become modified into some of the patterns seen in modern Rocky Mountain species. Quite a close general resemblance is shown by the abdominal pattern of *A. bernardinum*, but in that species the lateral subbasal dark spots are much nearer the middle line.

Anterior wings about 8 mm. long; *wings strongly infuscated*, except in the basal region, conspicuously hairy. Venation in general quite normal; *marginal cell broad*, its width about 720 μ; b. n. going only just basad of t. n.; first r. n. joining second s. m. a long distance (quite 420 μ) from base; discoidal nervure oblique and curved, so that *the second discoidal cell is conspicuously longer on lower than on upper side*, the upper outer corner being very obtusely rounded. Hind wing with t. m. long and very oblique.

Type. — No. 2002, Mus. Comp. Zoöl. Florissant, Col. (No. 11,381, S. H. Scudder Coll.). Dedicated to Mr. Scudder.

Anthidium exhumatum, sp. nov.

♂ Robust; length $13\frac{1}{2}$ mm.; width of head a little over 4, of thorax about 5, of abdomen about $5\frac{1}{2}$ mm., these measurements (particularly the last) no doubt increased by crushing; head and thorax black without any apparent markings; mesothorax coarsely roughened; ocelli large, not approaching eyes, distance between middle and lateral ocelli a little less than the diameter of one; abdomen with broad pale reddish bands, *the hind margins of the segments not darkened, nor any spots visible*; apex broadly rounded, no processes or teeth being visible, but a large quadrate area is occupied by the genitalia, the exact structure of which cannot be made out; hind tarsi apparently broad and flattened; hind tibiae with a rather abundant hairy scopa. *Wings colorless;* nervures pale; *marginal cell not so broad*

as in A. scudderi (its breadth about 570 μ); *stigma shorter and smaller,* more like that of Megachile; *second discoidal cell with the upper and lower sides about equal,* the upper apical corner hardly depressed; b. n. almost meeting t. m.; first r. n. passing some distance beyond first t. c.; second perhaps passing slightly beyond apex of second s. m.; second (morphologically third) t. c. strongly bent near the middle; t. m. of hind wing hard to see but oblique.

Type.—No. 2003, Mus. Comp. Zoöl. Florissant, Col. (No. 13,709, S. H. Scudder Coll.) and reverse of the same specimen (No. 11,388, S. H. Scudder Coll.).

This is not quite so typical an Anthidium as *A. scudderi,* but I think it cannot be referred to any other genus. These bees are referred to Anthidium and not to Megachile, not only because of the color of the abdomen, but also on account of the characters of the venation. The following comparison shows the difference in venation between *A. scudderi* and *Megachile calogaster:*

A. SCUDDERI.	M. CALOGASTER.
B. n. goes a little basad of t. m.	B. n. falls a little short of t. m.
First r. n. joins second s. m. at a distance from its base almost as great as half length of r. n.	First r. n. joins second s. m. at a distance from its base not greater than one quarter length of r. n.
Stigma larger and more pointed.	Stigma small and truncate.
Marginal cell conspicuously broader than greatest breadth of first s. m.	Marginal cell conspicuously narrower than greatest breadth of first s. m.
First discoidal much broader.	First discoidal long and narrow.
Second r. n. not well seen, but enters second s. m. at or very near tip.	Second r. n. enters second s. m. about as far from apex as first r. n. does from base.
T. m. of hind wing very oblique.	T. m. of hind wing not or hardly oblique.

Specimen No. 8444 is an Anthidium exactly agreeing with *A. exhumatum* in the width of the marginal cell and in the shape of the second discoidal, but having most of the venation obliterated. It differs by the strongly banded abdomen (suggestive of the living *A. occidentale*), which, however, is not spotted. It appears to be a female, and I little doubt that it represents that sex of *A. exhumatum.*

Dianthidium tertiarium, sp. nov.

♂ Body black or dark brown, without visible markings; head lacking; length, exclusive of head, about 8 mm.; width of thorax about $4\frac{3}{8}$, of abdomen about $4\frac{1}{2}$ mm.; anterior wing about 9 mm. long, slightly dusky, with the nervures dark; abdomen subglobose, terminating in two rather small and obscure tubercles, which are about as far distant as the breadth of the basal joint of hind tarsus at apex; posterior claws with a strong inner tooth. Venation of anterior wings normal; first r. n. ending about 300 μ from base of second s. m.; second r. n. passing about

120 μ beyond apex of second s. m.; marginal cell about 630 μ broad; first s. m. narrower than in *Anthidium exhumatum;* t. m. obliterated.

The general shape and the structure of apex of abdomen seem to indicate a species of the subgenus Anthidiellum, allied to the modern *D. gilense* Ckll. The venation agrees well with *D. gilense,* except that the first r. n. enters the second s. m. at a greater distance from the base and the marginal cell is more evenly rounded at apex.

Type. — No. 2004, Mus. Comp. Zoöl. Florissant, Col. (No. 806, S. H. Scudder Coll.).

Heriades laminarum, sp. nov.

Length 8 mm., robust, head and thorax black, abdomen very light reddish brown, doubtless red in life; width of abdomen 3 mm.; length of anterior wing about 4½ mm., venation pale reddish-brown; stigma fairly large, vein separating first s. m. from marginal cell; not quite as long as that separating stigma from marginal cell; marginal cell narrow and long, its width 300 μ, its apex rounded; first discoidal about 225 μ shorter than marginal; first s. m., on cubital nervure, about 675 μ long, r. n. about but its total length is about 810; second s. m. about 645 long, receiving first r. n. about 100 μ from base, and second r. n. hardly 30 from apex; b. n. bent, falling a little short of t. m.; t. m. in a line with lower part of b. n. (which shows that the bee is not a Panurgid); third discoidal shorter than in *H. truncorum.* T. m. of hind wing not at all oblique.

Type. — No. 2005, Mus. Comp., Zoöl. Florissant, Col. (No. 3062, S. H. Scudder Coll.). This looks like *Proteriades semirubra* (*Heriades semirubra* Ckll.), but it appears to be allied to the ordinary species of Heriades.

Heriades halictinus, sp. nov.

♀ Length slightly over 6 mm.; anterior wing about 4 mm.; stout-bodied, head and thorax black, abdomen dark brown; eyes narrow. Stigma large; marginal cell about 975 μ long and 255 wide, end rounded; length of first s. m. on cubital nervure about 555; length of second s. m. about 510, it is not greatly narrowed above, its outer margin presents a gentle double curve; lower edge of first s. m. straight; upper apical corner of second discoidal rounded; lower section of b. n. curved as in Halictus, meeting t. m.; first r. n. joining second s. m. at a distance from its base equal to about half length of first t. c.; second r. n. joining cell at its extreme apex; length of lower (curved) part of b. n. about 300 μ.

Type. — No. 2006, Mus. Comp. Zoöl. Florissant, Col. (No. 10,564, S. H. Scudder Coll.).

At first sight one would take this for a small Halictus, but the t. m. and various other characters indicate its true affinity. Compared with *Halictus similis*, the principal differences in venation are as follows:

(1) Straight section of b. n. (bounding first s. m.) almost as long as curved section (only about a quarter as long in *H. similis*).

(2) Only two submarginal cells.

(3) Second r. n. joining second (morphologically third) s. m. at extreme apex (far from apex of third in *H. similis*).

(4) Second (morphologically third) t. c. strong (third weak in *H. similis*).

(5) B. n. meets t. m., which is curved in an opposite direction to b. n., its lower end oblique and more basad than the upper (less basad in *H. similis*).

The *H. similis* used for comparison is the form obtained by Mr. Lovell in Maine.

From *Heriades laminarum*, the present species is easily known by its darker abdomen and smaller size, as shown especially in the wing-measurements.

Heriades bowditchi, sp. nov.

No. 13,761 is larger (length, with the head thrust forward, 10 mm.); the thorax was evidently very coarsely punctate, the punctures contiguous; the following measurements are in μ; curved portion of b. n., 300; straight portion a little longer; width of marginal cell, 300; its length, about 1350. The t. m. is as in the other species. Head large, slightly wider than thorax; abdomen light-colored, with the apex brown (doubtless black in life), and two broad entire brown bands on the apical half. The anterior wing (not perfectly preserved) must have been a trifle over 5 mm. long. This differs from *H. laminarum* by the very decidedly larger head, and the banded abdomen. The apex of the marginal cell, seen from one direction, seems to be very obliquely truncate, but this may be illusory. The stigma is pale, but it is certainly much longer, and more slender than in *H. laminarum*.

A second example (No. 13,436, S. H. Scudder Coll.) confirms the validity of this species. The specimen is clearly a ♀.

The abdomen has broad entire reddish-brown bands on the first four segments, that on the first being faint; the marginal cell is pointed at tip, not obliquely truncate; its length, measured in this specimen, is the same as in the type. The t. m. curves inwards below, as in the type. The legs are hairy.

Type. — No. 2007, Mus. Comp. Zoöl. Florissant, Col. (No. 13,761, S. H. Scudder Coll.). Named after Mr. F. C. Bowditch, Mr. Scudder's companion at Florissant.

ANTHOPHORIDAE.

Calyptapis, gen. nov.

Stigma small but rather broad, about like that of Melissodes, the part within the marginal cell smaller than that without; marginal cell large and broad, the tip away from costa, obtusely rounded, not at all appendiculate; three submarginal cells, *the third very long, and considerably the longest*, narrowed a little more than half to marginal; the third t. c. with a very distinct double curve, *but not abruptly bent*, the cell (third s. m.) slightly appendiculate at its apical point, which is not far from the point of junction of the second r. n., the latter joining at the end of the straight lower margin, at the beginning of the upward curve, about as in *Melissodes atripes*; *second s. m. pentagonal*, the lower inner corner produced to considerably less than a right angle; the cell is rather large, broader below than high, narrowing above,

from the obliquity of the first t. c.; *it receives first r. n. before the middle,* at a point almost beneath the upper insertion of the first t. c.; first s. m. longer and larger than second, but not very greatly so, its lower margin gently curved, giving it a considerable breadth; b. n. straight, except near the basad end, where it bends downwards, *and is attached a short distance basad of the t. m.;* t. m. not oblique; second r. n. gently curved outwards, *its junction with the third s. m. forming an angle greater than a right angle;* second discoidal cell longer below than above, but not very greatly; *first discoidal not so long as marginal, but not greatly shorter.* The structural characters of the body cannot be ascertained.

Calyptapis florissantensis, sp. nov.

Black; anterior wing 8 mm. long, venation distinct, brown. The following measurements are in μ: width of marginal cell, 630; length of t. m., 300; width of second discoidal cell at apex, 825; from insertion of second r. n. to appendix at end of third s. m., 135; distance between insertion of first r. n. and base of second s. m., 375; length of b. n. about 1875.

Type. — 2008, Mus. Com. Zoöl. Florissant, Col. (No. 4933, S. H. Scudder Coll.).

So far as the venation goes, this genus is not far from certain species of the modern Melissodes. If it were a living insect, differing from Melissodes only in the manner indicated, it might be held to typify only a subgeneric group; but under the circumstances, and with a probability that the mouth-parts, etc., if preserved, would afford additional characters, it seems best to treat it as a distinct genus. It is probably too much to hope that fossil Anthophoridae will ever be found, showing adequately the palpi and other minute characters so useful in segregating modern genera.

ANDRENIDAE.

Libellulapis, gen. nov.

♀ Eyes apparently very prominent, the anterior part of face produced; first s. m. not so long; second discoidal narrower at end; second r. n. curved or bent outwards (straight in Parandrena); size small, abdomen conspicuously banded. The head, as preserved, has a singular resemblance to that of a dragonfly.

Libellulapis antiquorum, sp. nov.

♀ Length about 6 mm.; anterior wing about 5 mm.; width of thorax about $2\frac{1}{3}$, of abdomen about 2 mm. Head and thorax black; eyes prominent; flagellum stout; abdomen colorless, with a large brown patch on each side of middle of third segment; segments 4 and 5 each with a very broad entire brown band; 6 with a fainter band; middle and hind femora stout; venation brown; stigma large, but rather slender, with a large part in marginal cell, width of stigma about 195 μ (all the following measurements are in μ); marginal cell long and narrow, the tip on costa, width of cell about 300; b. n. practically straight, except a slight bend at proximal end, meeting t. m., which is oblique, at least 45° out of the straight line

with b. n.; first s. m. on cubital nervure about 630 long, its lower edge straight (which distinguishes it from Halictoides); second the same length, but only 360 long on marginal, the second t. c. with a double curve; first r. n. entering second s. m. about 150 from base, second about 60 from apex; breadth of second discoidal at base 195, at apex about 390. Compared with *Halictoides maurus* it differs by the second s. m. being much broader above, and receiving the second r. n. nearer its end, by the larger and narrower second discoidal, and the lower edge of first s. m. practically straight. Compared with *Hesperapis rhodoceratus*, the insertion of the recurrent nervures is different, and the second r. n. in particular is quite different in its direction, etc.; the straight lower edge of first s. m. agrees. Compared with *Parandrena andrenoides*, the stigma is smaller, and the second discoidal is not so broad apically. It does not agree with Diandrena or Biareolina.

Type. — No. 2009, Mus. Comp. Zoöl. Florissant, Col. (No. 9061, S. H. Scudder Coll.).

A second example (No. 8560, S. H. Scudder Coll.) shows that the legs are dark and hairy; the mandibles bidentate, the inner tooth rounded and small; flagellum about 195 μ broad; abdominal bands not well preserved, but a dark patch at apex. This example shows the same curiously prominent eyes as the type, hence it does not seem likely that the feature can be due in some accident of crushing. The eyes stand out on each side of the head to an extent of at least 300 μ, forming an angle with the anterior part of the face, which appears quadrate, twice as broad as long. The eyes of Parandrena are prominent, especially in the male, but they do not look like those of Libellulapis.

Halictus florissantellus, sp. nov.

♀ Length about 6½ mm.; stout-bodied; head, thorax, abdomen, and legs black; width of thorax 2 mm., of abdomen slightly more; length of anterior wing somewhat over 4 mm., stigma and nervures dark; middle tibia very much broader than basal joint of its tarsus (breadth of tibia 263 μ, of basal joint of tarsus 120); b. n. strongly curved, normal for Halictus, curved part 465 μ long, straight (upper) part about 150; t. m. a little oblique, a little basad of b. n., but not separated from it by an interval, its lower end more apicad, as is normal for Halictus; width of second discoidal at base 225; stigma large, about 165 μ broad; marginal cell about 270 broad, ending in a point on costa; wings quite hairy in costal region anterior to stigma; first r. n. joining cubital nervure 690 μ from base; submarginal cells not traceable.

Type. — No. 2010, Mus. Comp. Zoöl. Florissant, Col. (No. 921, S. H. Scudder Coll.).

Although only part of the venation is preserved, this, and the general appearance of the insect, agree with Halictus, and the generic reference seems safe.

Halictus scudderiellus, sp. nov.

♀ Length about 4½ mm., anterior wing about 2⅘; intense black, including legs except tarsi, which are pale reddish; antennae stout, breadth of flagellum about

150 μ; legs normal, breadth of hind tibiae about 255 μ, of the basal joint of their tarsi about 150; dorso-ventral diameter of abdomen about 1350 μ, length of head about the same; costa somewhat arched; stigma large and black; marginal cell about 900 μ long and 195 wide, ending in a point on costa; first section of b. n. about 150 μ long; second section curved, fully 375 μ long; second s. m. on marginal a little over 150 μ long, on cubital nervure slightly over 300, the second t. c. curved outwards.

Type. — No. 2011, Mus. Comp. Zoöl. Florissant, Col. (No. 1966, S. H. Scudder Coll.).

Lithandrena, gen. nov.

A genus of Andreninae, allied to Andrena. It differs from Andrena and Nomia in the second r. n., which is strongly bent in its upper part, straight but oblique below; from Andrena it differs in the proportions of the submarginal cells (see the dimensions given below); and from Nomia by the tip of the marginal cell, which is pointed, and a little away from costa. The general appearance is that of an Andrena, but it cannot be referred to that or any other genus known to me. In Cresson's table it seems to run to Ceratina, but it is not allied to that genus.

Lithandrena saxorum, sp. nov.

♀ Length 8⅔ mm., anterior wing about 5⅓; diameter of thorax 3, head the same, of abdomen 3½ mm.; head and thorax black; abdomen light, with a broad entire dark band on each segment; legs hairy; flagellum rather stout, diameter 195 μ. In the following account of the anterior wing the measurements are in μ: stigma well-developed, diameter 175, length of the part within marginal cell 360; marginal cell long and pointed, length 1620, breadth 405, apex pointed, away from costa, but distance from apex to opposite point on costa scarcely 65; three submarginal cells; total length of first s. m. 900, but its length on cubital nervure only 570, the first t. c. being remarkably oblique, and having its lower part curved; length of second s. m. on cubital nervure 615, but it is greatly narrowed above, its length on marginal being only 150; first r. n. joining second s. m. 90 from end; length of third s. m. about 675, but it is greatly narrowed to marginal, its length above being about 270; second r. n. with a strong bend at the end of the upper two fifths, the lower three fifths straight; length of first discoidal cell 1650; b. n. meeting t. m.; lower section of b. n. slightly curved (but not more so than in some forms of Andrena), and more than twice as long as upper one (length of lower section 630, of upper 300); t. m. oblique, its lower end more apicad (as in Andrenines, Panurgids, etc.)

Type. — No. 2012, Mus. Com. Zoöl. Florissant, Col. (No. 8219, S. H. Scudder Coll.).

Andrena sepulta, sp. nov.

♀. Length 9 mm.; width of thorax 2½ mm., of head and abdomen about the same; abdomen of normal shape; flagellum stout; there is an appearance as if the eyes nearly met on the vertex, but I think this is illusory, resulting from the

way the head is crushed; head and thorax black; abdomen nearly colorless, with broad suffused reddish-brown bands on apical margins of the first three segments, the apex also dark; abdomen hairy all over; legs light reddish-brown, hind tibia about $1\frac{2}{8}$ mm. long, tarsi hairy; wings very hairy. The following wing-measurements are all in μ: stigma large, pointed apically, width about 300, part within marginal cell about 450 long; marginal cell long and pointed, the apex on costa, length of cell 1605, breadth 375; three submarginals, first and third long, second short, much narrowed above, almost triangular, third much narrowed above; first s. m. on cubital nervure 810, its total length 1125; second s. m. on cubital n., 405, on marginal, 135; third s. m. on cubital n., 720, on marginal, 330; bend of third t. c. about 210 from cubital n.; first r. n. enters second s. m. at extreme apex, second enters third s. m. about 90 from apex; second r. n. leaves cubital n. at a right angle, but gently curves inwards, being nowhere at all bent; upper section of b. n. 330; lower section 630; lower section gently curved, but not at all as in the Halictines; b. n. falling about 60 short of t. m., which is oblique, its lower end more apicad.

Type. — No. 2013, Mus. Comp. Zoöl. Florissant, Col. (No. 14,288, S. H. Scudder Coll.). The venation is not exactly like that of any modern species with which I have compared it, but the differences are unimportant.

Andrena (?) clavula, sp. nov.

♀. Length 8. mm.; width of thorax 3, of head 2; length of anterior wing $6\frac{2}{8}$ mm.; eyes ordinary; flagellum stout, subclavate, rather short, about 300 μ broad near end; head and thorax black, femora dark; hind tibiae and tarsi apparently pale, but middle tibiae dark; wings somewhat dusky; abdomen subclavate, dark reddish-brown, with three rather narrow pale bands, occupying hind margins of segments 2 to 4 and the extreme bases of the adjacent segments.

Venation (front wings) as in *A. sepulta*, except that second s. m. is narrower and more parallel-sided. Measurements in μ: width of stigma 240; length of marginal cell about 1455, its width 360; lower section of b. n., 630; second s. m. on cubital n., 360, on marginal, 155.

Type. — No. 2014, Mus. Comp. Zoöl. Florissant, Col. (No. 6963, S. H. Scudder Coll.). The shape of the abdomen is like that of a ♀ Ceratina, or possibly certain Halictines, but the venation does not agree with these. As the venation is exactly the same (speaking generically) as that of *A. sepulta*, it seems that the insect should be considered congeneric.

SPHECOIDEA.

CRABRONIDAE.

Tracheliodes mortuellus, sp. nov.

Black; length 7 mm. or somewhat more; abdomen petiolate; wings short; metathorax coarsely striate or ridged; upper posterior part of pleura finely striatulate; ocelli large, in a fairly high but not nearly equilateral triangle; mandibles stout, bent inwards apically (*i. e.* the outer edge becoming very convex), with the

cutting edge sinuate, but not distinctly bidentate; venation nearly as Kohl figures for *Tracheliodes megerlei* (*Brachymerus megerlei* Dahlb.), but having the stigma longer and narrower; the cells are practically the same; the costal cell is almost obsolete. Measurements in μ: length of marginal cell, 705; its breadth, 225; its breadth at the truncate end, 135; length of stigma, 420; its breadth, 105; length of s. m., 750; length of first discoidal cell, also 750; length of second discoidal, 540; r. n. joining s. m. at middle; t. m. a short distance basad of b. n.

Type. — No. 2015, Mus. Comp. Zoöl. Florissant, Col. (No. 3200, S. H. Scudder Coll.). I use the name proposed by Morawitz (1866) for this genus, because Brachymerus Dahlbom, 1845, though earlier, is a homonym. The genus has not hitherto been recognized in America, and it may be that if all the parts (*e. g.* of the mouth, etc.) of the extinct form could be examined, it would be found generically separable. At present, however, I can find no grounds for separation.

PEMPHREDONIDAE.

Passaloecus scudderi, sp. nov.

Length $6\frac{1}{2}$ mm.; black, with a large, broad (width about $2\frac{1}{2}$ mm.) head, globose thorax, and narrow sessile abdomen; breadth of thorax $2\frac{1}{2}$, of abdomen about $1\frac{1}{2}$ mm., hind margins of abdominal segments broadly rather pale brown; ocelli normal; anterior wing about $3\frac{1}{2}$ mm. long, venation rather pale brown; stigma rather large, about 135 μ broad; marginal cell normal; first s. m. about 780 μ long; second s. m. 255 long and about 375 high, its sides parallel; b. n. strongly curved; first r. n. entering first s. m. about 135 μ from its end; second r. n. joining second s. m. very slightly beyond the middle; apical corner of first discoidal rather more elongated and pointed than usual; b. n. falling a little short of t. m.; second discoidal oblique, slanting downwards apicad.

Type. — No. 2016, Mus. Comp. Zoöl. Florissant, Col. (No. 8758, S. H. Scudder Coll.). Closely allied to existing United States species.

PHILANTHIDAE.

Prophilanthus, gen. nov.

Large and robust, with a sessile abdomen; stigma little developed; marginal cell narrowly but very obtusely rounded at apex, the apical point away from costa, and quite without an appendix; third submarginal cell very broad, and equally broad above and below; basal nervure joining subcostal a long way basad of stigma. Compared with *Philanthus albifrons* Cresson, the fossil insect showed the following differences: —

(1) Portion of stigma in marginal cell shorter.

(2) Marginal cell bulging basally, *i. e.*, in the direction of the first t. c.

(3) Marginal cell with apex rounded, the apical point not on costa.

(4) Third t. c. arched, with more or less of a double curve (a character of Philoponus).

(5) Second s. m. broader, and receiving first r. n. more distinctly before middle.

(6) Third s. m. very much broader above, being equally broad ($1050\,\mu$) above and below.

(7) Prothorax, mesothorax, and metathorax longitudinally striate, especially the prothorax. (Very faint striation of the prothorax is visible in *P. albifrons.*)

Other characters are: width of third discoidal at base somewhat less than greatest width of first discoidal; first t. c. not angulated at basal third; second discoidal cell more than twice as long as its width at apex; cubital nervure not bent, but slightly curved downwards, at end of first discoidal; lower section of b. n. (bordering first discoidal) about twice as long as upper.

Prophilanthus destructus, sp. nov.

Length about 20 mm., robust, with a thick sessile abdomen, which appears to have had very broad black bands alternating with narrower yellow ones; antennae 6 mm. long, ordinary, the scape thick, flagellum black; length of anterior wing 12½ mm.; costa, up to base of marginal cell, broadly and very deeply infuscated, apex also clouded; marginal cell 3 mm. long, only just surpassing apex of third s. m.; first s. m. 3 mm. long; second and third submarginal cells combined, on cubital nervure, 3 mm. long; first discoidal cell 4½ mm. long, or nearly; second r. n. nearly straight, slightly bowed outwards; second s. m. very broad below; origin of first t. c. to insertion of first r. n., $450\,\mu$; insertion of first r. n. to origin of second t. c., $975\,\mu$; origin of second t. c. to insertion of second r. n., less than $150\,\mu$.

Type. — No. 2017, Mus. Comp. Zoöl. Florissant, Col. (No. 7762, S. H. Scudder Coll.).

NYSSONIDAE.

Hoplisidia, gen. nov.

Size rather large; thorax hairy, the hairs long and quite simple; abdomen subcylindrical, broadest at the apex of second segment; first segment comparatively small, but not petiolate; apex pointed; the form of the insect like Gorytes or Hoplisus; stigma very narrow, almost obsolete; three submarginal cells, the first at least as long as the other two combined, the b. n. joining subcostal very far basad of the stigma; second s. m. broad, receiving the recurrent nervures near the end of the first and second thirds, the second r. n. curved and bent backwards to its point of insertion; third s. m. about twice as broad below as above; marginal cell narrowly rounded at apex; first discoidal conspicuously longer than marginal; b. n. sharply bent at origin of cubital; b. n. meeting t. m., or practically so; hind wings with cubital nervure exactly meeting t. m., which goes downwards for a short distance, and is then bent, finishing its course very obliquely. Among the Gorytinae, this falls closest to Hoplisus by the venation of the hind wings. It is peculiar for the very long first s. m., the b. n. meeting t. m., the reduced stigma, and the long first discoidal, the whole combination seeming to exclude it from the modern genera. The upper apical corner of the second discoidal is obtuse, as in *Gorytes mystaceus*, not acute as in *G.* (*Hoplisus*) *quadrifasciatus.* The second t. c. is much less oblique than in either of the species just cited, being very nearly vertical, and not at all parallel with the third t. c.

Hoplisidia kohliana, sp. nov.

Length (but in a somewhat disintegrated condition) about 20 mm.; anterior wings about 11½ mm., with a dusky cloud in the second s. m., and suffusedly below; length of abdomen about 10 mm., its width 4; measurements in μ: — length of marginal cell about 2250; its breadth 525; length of first s. m. about 2475; length of second s. m. on marginal, about 600; on cubital nervure about 1050; of third s. m. on marginal 600, and on cubital 1140; insertion of first r. n. from first t. c. 420; insertion of second r. n. from second t. c., 300; length of first discoidal, 3300.

Type. — No. 2018, Mus. Comp. Zoöl. Florissant, Col. (No. 742, S. H. Scudder Coll.). Named after the author of the most useful work on the genera of fossorial wasps.

Hoplisus sepultus, sp. nov.

Probable length about 10 mm. (head, much of thorax, and base of wings missing in the type); abdomen sessile, apparently normal, curved downwards as though in the act of stinging; hind tibia with tarsus about 4½ mm.; wings with a dark cloud in base of marginal cell, filling second s. m., and extending suffusedly below, still showing brilliant iridescent colors, especially in second s. m.; nervures more slender than in *Hoplisidia kohliana;* stigma large, its breadth about 170 (this and all following measurements in μ); marginal cell about 1500 long and 300 broad, pointed on costa; b. n. beginning at or very near base of stigma, and going a little basad of t. m.; length of first s. m. about 1275; second s. m. hexagonal, its length on marginal 300, on oblique apex of first discoidal 170 to 270 (this variation in the opposite wings of the same individual); first recurrent nervure to second (both received by second s. m.) 300; second r. n. to origin of second t. c. 150; third s. m. oblique, its greatest length (from upper basal to lower apical corners) 1125, its length on marginal 450, its length on cubital nervure 750, its tip surpassing marginal cell a little; insertion of third t. c. to tip of marginal cell 570; length of first discoidal about 2100; second r. n. very strongly bowed outwards. Hind wing reversed in the specimen; cubital nervure meeting t. m.; distance from t. m. to t. c. 1800.

Type. — No. 2019, Mus. Comp. Zoöl. Florissant, Col. (No. 980, S. H. Scudder Coll.).

No. 2710, S. H. Scudder Coll., is a wing of *Hoplisus sepultus*, with a small portion of the body. The measurements are in part greater than in the type indicating perhaps the opposite sex or a larger individual, but evidently not another species. Length of marginal cell about 1500, its breadth about 300; length of first submarginal about 1350, the b. n. hardly going so near stigma as in type; second s. m. on marginal 240; distance between first and second recurrent nervures at insertion 300; length of first r. n. 750 (same in type); insertion of second r. n. to origin of second t. c. 150; greatest length of third s. m. about 1200; third s. m. on marginal 570; length of third t. c. 795; insertion of third t. c. to apex of marginal cell 600. Cloud in second s. m., etc., as in type.

SPHECIDAE.

Ammophila antiquella, sp. nov.

Head and thorax black; abdomen all light; hind legs apparently light, with the tarsi black, in strong contrast; form slender. Length 12 mm.; abdomen $7\frac{1}{3}$ mm., of which 3 mm. is petiole; width of thorax between wings $1\frac{3}{5}$ mm., of head perhaps a trifle less; hind tibia $2\frac{3}{4}$ mm.; scape rather stout, as usual in the genus, metathorax transversely striated; wings not preserved. Anteriorly to the transversely striate area on thorax, some longitudinal striae can be seen. The petiole of abdomen is two jointed, the first joint scarcely over one third the length of the second; the breadth of the apical part of the abdomen is $1\frac{1}{2}$ mm.

Type. — No. 2020, Mus. Comp. Zoöl. Florissant, Col. (No. 5974, S. H. Scudder Coll.). The specimen is poorly preserved, but as its relationships are evident, it is described.

VESPOIDEA.

SCOLIIDAE.

I here use this family name in a rather broad sense, including the Myzinidae and Tiphiidae of Ashmead. The two extinct genera here introduced are evidently related to the Tiphiid series, though not without features suggestive of the other groups. So far as I am able to judge, their affinity is closest with the rare and apparently primitive genus Engycystis Fox, found in Texas and Lower California. Curiously, however, a new genus from Australia is also related, and for purposes of comparison is herewith described. The following table separates the four genera from each other: —

Basal nervure entering subcostal at a distance from stigma much greater than length of stigma . . . . *Austrotiphia*, gen. nov.
Basal nervure entering subcostal at a distance from stigma less than length of stigma 1
1. T. m. strongly oblique; stigma very narrow, not nearly filling the large stigmatic cell; marginal cell not surpassing third s. m. . . . . *Lithotiphia*, gen. nov.
T. m. slightly oblique 2
2. Marginal cell surpassing third s. m., its apex rounded; costal cell large. *Geotiphia*, gen. nov.
Third s. m. surpassing marginal cell; apex of marginal pointed, on costa; costal cell small or rudimentary . . . . *Engycystis* Fox.

In Engycystis, the ventral constriction between the first and second abdominal segments is not nearly so marked as in Tiphia and Paratiphia, but in Austrotiphia the constriction is still less evident, being hardly appreciable. One would almost hesitate to place the latter genus in the Scoliids, were it not so obviously a Tiphiid in every other feature. The otherwise different Australian

genus Dimorphoptera Smith, appears to share the same character. Unfortunately this character cannot be determined in the fossil genera, owing to the position of the specimens.

♀ Having exactly the appearance of a Tiphia, but related to Engycystis, from which it differs thus: basal nervure joining subcostal much more remote from stigma; first s. m. long, broken by a false vein which passes from near the origin of the first t. c. to near the base of the stigma (the same is found in the Myzinid Plesia); marginal cell broadly rounded, — almost truncate, at apex; second s. m. extremely broad below, the first and second s. ms. exceedingly oblique; first discoidal cell at base narrower than first submarginal; t. m. very oblique (a character of the fossil Lithotiphia); hind wings with t. c. oblique (its upper end more basad), and cubital nervure ending about as far basad of upper end of t. m., as half the length of the latter. Stigma well-developed.

Austrotiphia kirbyi, sp. nov. ♀. Length about 13 mm., entirely black, looking like an ordinary Tiphia; eyes and mandibles as in Tiphia, simple; punctures nearly as usual in Tiphia; hind margin of prothorax straight, or rather gently concave, with no median lobe; anterior part of mesothorax smooth; scutellum shining, with very sparse and small punctures; parapsidal grooves very strong; tegulae small; abdomen with small punctures, closer and much smaller and more regular on basal part of segments; apical ventral plate not greatly surpassing dorsal; legs much as in Tiphia, but hind femora much broadened, sharply keeled below; hind tibiae short, with five or six rather broad teeth on outer edge; basal joint of hind tarsus tuberculate on outer side, not spined; middle and hind tibiae each with two white spurs; last joint of hind tarsi normal. Shoalhaven, Australia (W. W. Froggatt, 186). Captured in 1895, and now the property of the British Museum. Named after Mr. W. F. Kirby, in recognition of his work on Scoliidae.

In Geotiphia the teeth on the outer edge of the hind tibia are very broad, not spine-like as they are in Tiphia and Engycystis. In Austrotiphia they are comparatively broad and short, and the last one, in particular, recalls that of Geotiphia. In Tiphia the suture between the first two abdominal segments is evidently depressed at the sides, the abdomen being viewed from above; this is not the case in Austrotiphia. In this particular, so far as can be seen, Geotiphia and Lithotiphia resemble Austrotiphia. Geotiphia has some appearance of having had emarginate eyes, a character of the true Scoliids, but it is impossible to be sure about it. The spotted abdomen is also suggestive of the Scoliids, but not so the venation and the large stigma. When one uses the compound microscope to examine the eyes, the appearance of emargination disappears, and so far as can be seen, they look normal for the Tiphiidae. On the hind leg of the ♀, the tibial spurs are very short in Engycystis, very much less than half the length of the first tarsal joint; in Austrotiphia these spurs are very long, the longest (the hind one) being fully three quarters the length of the first tarsal joint; in the two fossil genera their character has not been determined. Tiphia has them long, like Austrotiphia. The second antennal joint in Austrotiphia is conspicuously smaller than in Tiphia. In Geotiphia the middle joints of flagellum are broader than long; in Austrotiphia (♀) they are about as long as broad;

in Tiphia (♀) they are conspicuously longer than broad. In Geotiphia and Tiphia the claws are bifid; in Austrotiphia they appear at first sight to be simple, because the inner tooth is flattened, shortened, and directed somewhat inwards. In Tiphia the middle coxae are very widely separated by a bilobed projection of the mesosternum; in Austrotiphia they are considerably closer together, the bilobed projection, although present, being much smaller. In Engycystis they are more as in Austrotiphia. In Tiphia the middle tibiae have only one spur, in Austrotiphia and Engycystis (as in the Myzinids) there are two. Tiphia has an open marginal cell and only two submarginals; Austrotiphia, Engycystis, Geotiphia, and Lithotiphia have a closed marginal and three submarginals.

Geotiphia, gen. nov. **foxiana**, sp. nov.

Length about $11\frac{1}{2}$ mm.; black, with light markings on abdomen; femora black, tibiae and tarsi light, probably red in life; the abdominal markings, presumably yellow in life, consist of a broad transverse spot or patch on the first segment, rounded at sides and deeply emarginate posteriorly, a couple of transversely oval spots on second segment, and a pair of smaller and rounder ones on third; first segment broad, broadly rounded in front; width of abdomen about 3 mm.; head round, width about 2 mm.; middle joints of flagellum about 180 μ long and 225 broad; middle tibia apparently short, broad (breadth about 300 μ), abruptly truncate; middle tarsi slender, first joint about 900 μ long, its outer edge straight on first half and convex on second, third and fourth joints each about 225 μ long, and quite slender; claw joint (excluding claws) about 300 μ long; claws bifid, the two teeth about equally long; hind femora stout but not at all subglobose, about 1500 μ long; hind tibia about as long, about 600 μ broad; basal joint of hind tarsus about 250 μ broad. Outer apical edge of hind tibiae with very broad teeth, with points directed apicad, and long straight or nearly straight upper edges. Wings with a large stigma (solid, filling stigmal cell), its breadth about 300 (this and all following measurements in μ); costal cell very distinct, the costal and subcostal nervures very heavy, and quite wide apart; marginal cell complete, broadly rounded at end, the actual apex not on costa, length of the cell 1500 μ, its tip surpassing apical point of third s. m. by about 100, although the distance from insertion of third t. c. to apex of marginal is about 450; three submarginal cells, the first 1200 long; second very broad, 450 long on marginal, and 900 on cubital nervure, receiving the first r. n. exactly at the middle; third s. m. 600 long on marginal, its outer side strongly bulging; first (upper) section of b. n. less than 300 long, bulging at its lower end, just before the origin of cubital nervure; second (lower) section slightly over 300 long, meeting t. m., which is a little oblique; first discoidal 1500 long; second r. n. joining third s. m. not far from the middle.

Type. — No. 2021, Mus. Comp. Zool. Florissant, Col. (No. 14,292. S. H. Scudder Coll.). Named after Mr. W. J. Fox, in recognition of his work on Engycystis.

Lithotiphia, gen. nov. scudderi, sp. nov.

Length about $12\frac{1}{2}$ mm., anterior wing about $8\frac{1}{3}$; black, the abdomen without light spots; head round, its width $2\frac{1}{2}$ mm.; width of thorax (doubtless increased by crushing) about 4 mm.; abdomen about $6\frac{2}{3}$ mm. long and 3 broad; hind femora cylindrical, rather stout, with a little concavity followed by a prominence at apex beneath, as in other Tiphiids; hind tibiae greatly swollen, apparently not dentate; hind tarsi very slender. Wings with apparently a very large stigma, but the microscope shows that this is the stigmal cell, not nearly filled by the long and slender true stigma, which is brown, as long as stigmal cell, but only about 105 (this and all following measurements in μ) broad; the stigmal cell is about 675 long, and 255 broad, broadly truncate posteriorly, and with a rudimentary cross-nervure before the middle, almost meeting the radial nervure (in a modern Scolia I can detect such a cross-nervure, but still more rudimentary); marginal cell entire, exceedingly broadly rounded apically, the actual tip not on costa, length of the cell 1650; three submarginals, the second very broad, 750 long on marginal, receiving the first r. n. nearly 600 from its beginning, and 450 from its end; third s. m. broadly bulging apically, not surpassed by the marginal; length of third s. m. on marginal 750 (same as second s. m.); second r. n. joining third s. m. 375 from its base, and 450 from its lower apical corner; the second r. n. joins the cubital nervure in such a way that the outer angle formed is less than a right angle. B. n. going very slightly basad of t. m., which is strongly oblique.

Type. — No. 2022, Mus. Comp. Zoöl. Florissant, Col. (No. 2440, S. H. Scudder Coll.).

POMPILIDAE.

Hemipogonius florissantensis, sp. nov.

Length nearly 15 mm., anterior wing about 10 mm.; anterior wings with a transverse dark cloud or suffused band at about the end of the basal third, a very large dark roundish patch in and below the marginal cell, and the tip dusky, a round area between the dusky tip and the large dark region appearing white. General structure of body normal, the abdomen sessile, with the first segment, seen in lateral profile, ascending and convex; spurs large; antennae about 7 mm. long, one curled under body reaching middle coxae, apparently not curled, or little curled, at tip; hind coxae long, hind femora about $3\frac{1}{2}$ mm.

Length of stigma 900 (this and the following measurements in μ), its breadth about 285; costal cell distinct; length of marginal cell about 2400, long and narrow, its breadth about 525, its apex pointed and on costa; distance from insertion of third t. c. to tip of marginal, 765; length of first s. m. nearly 2250; first t. c. bowed inwards (basad), its length about 525; stigma to insertion of first t. c., 270; second s. m. on marginal, 750; third s. m. on marginal, 795; outer angle formed by insertion of third t. c. on marginal less than a right angle; distance from insertion of second r. n. to lower apical corner of third s. m., 825 (the second r. n. enters third s. m. toward the base); b. n. *very* far basad of stigma, and its origin 450 basad of t. m., its lower section about 600 long, the upper one (bounding first s. m.) considerably less; lower edge of second discoidal 1275 long, its breadth at apex

800, at base 300. Hind wings with cubital nervure inserted a short distance beyond (apicad of) t. m.

Type. — No. 2023, Mus. Comp. Zoöl. Florissant, Col. (No. 8647, S. H. Scudder Coll.). Easily known from *H. scudderi* by its larger size. The specimen shows several venational characters which were not preserved in *H. scudderi*, and they confirm the generic reference.

Hemipogonius scudderi, sp. nov.

Slender, length about 10½ mm.; antennae 5⅝ mm., the scape thickened; width of head 2 mm.; length of anterior wing about 6½; length of thorax almost 3½; of hind tibia and tarsus about 7; hind spurs large. Wings hairy; stigma distinct; marginal cell sharply pointed on costa, its length and that of first s. m. the same, 1575 μ; greatest width of marginal cell only 405 μ; second s. m. pentagonal, broad, receiving first r. n. a little beyond its middle; length of second s. m. on marginal 450 μ; third s. m. larger than second, shaped as usual; b. n. about 120 μ basad of t. m.; t. m. 255 μ long, not at all oblique. Stigma dark, and a dark cloud in the region of b. n. and below; also a diffused brown cloud occupying marginal cell, the second and third submarginals, and the third discoidal; this region still shows bright iridescent colors. Somewhat allied to the living *H. alienatus* (Smith), but larger. The wings are shorter, and much more strongly clouded, than in *H. fortis* (Cresson) The sutures of the antennal joints are black.

Type. — No. 2024, Mus. Comp. Zoöl. Florissant, Col. (No. 8640, S. H. Scudder Coll.). A beautifully preserved specimen. No. 10,813, S. H. Scudder Coll., is the reverse of the same example.

Ceropalites, gen. nov.

Abdomen very convex, the first point narrowed to a distinct petiole; stigma very well-developed, elongate, lanceolate; subcostal nervure quite widely separated from costa; first discoidal cell very narrow, the part of the basal nervure bounding it being less than half as long as the part bounding first submarginal; b. n. passing only just basad of t. m.; marginal cell large and elongate, probably pointed; antennae long.

Ceropalites infelix, sp. nov.

Length 13 mm.; as preserved, entirely light reddish-brown, probably red in life; wings hyaline, with the apical margin broadly dusky; stigma dark, with a brownish spot immediately below it; length of anterior wing 10 mm.; of abdomen 7; height of abdomen (dorso-ventral) 3; length of thorax anterior to wings 1½ mm.; length of marginal cell over 4 mm. (the apex gone); of wing anterior to stigma about 5½ mm.; length of stigma about 1500 μ; its breadth about 375; first section of radial nervure, passing almost straight down from stigma to junction of first t. c., about 450 μ long; width of marginal cell 1095 μ; from first to second t. c. on radial nervure about 1650 μ; beginning of b. n. from stigma, 600 μ; distance of subcostal nervure from costa at this point, 300; first (upper) part of b. n. about 1110 μ, second (lower) part 390; hind part of metathorax with some transverse keels.

Type. — No. 2025, Mus. Comp. Zoöl. Florissant, Col. (No. 6013, S. H. Scudder Coll.). The first abdominal segment having a distinct though short (less than 1 mm. long) petiole is suggestive of Sphecidae, but the insect does not otherwise agree with that group. The first abdominal segment really recalls the winged Mutillidae allied to Photopsis, as much as anything; but the ventral surface of the abdomen is perfectly straight (or rather, gently convex), without the least sign of a depression between the first and second segments. The well-developed stigma is suggestive of Ceropales, but the venation differs from that of any modern genus known to me. I cannot see the third submarginal cell distinctly, but it appears to have been present. The dark spot below the stigma is still slightly iridescent.

VESPIDAE.

Palaeovespa, gen. nov.

With the general form of Vespa, the thorax broadly rounded, and the abdomen sessile and broad at base; the first segment of transverse form, yet by no means so broad as in true Vespa. Venation more like Polistes, the marginal cell being pointed, the apex of first discoidal oblique, and the recurrent nervures joining the second s. m. far apart, not both entering the basal half of the cell, as in Vespa. The b. n. joins the subcostal nervure nearer to the stigma than is usual in Vespa, but not at its base, as in Polistes. It is impossible to see whether the hind wings have an anal lobe or not. This is a very interesting genus, having the appearance rather of Vespa (it would never occur to any one to refer the specimens to Polistes), but retaining the apparently more primitive venation of Polistes, or a close approximation to it. *P. florissantia*, the largest species, is taken as the type, but the characters of the genus are not all ascertainable from the single specimen of that insect.

Palaeovespa florissantia, sp. nov.

Very large and robust; length to beyond middle of fifth abdominal segment, 25 mm.; length from base of abdomen to apex of fourth segment, 14 mm.; thorax narrow for the size of the insect, its width between wings about 7 mm.; breadth of abdominal segments in mm. (1) 6½, (2) 8½, (3) 8⅘; color dark, evidently black in life, with the hind margins of the abdominal segments broadly but suffusedly pallid; no distinct abdominal markings; wings apparently reddish. The venation is obscure, but the wings appear to be folded, and the very long first discoidal cell of the Vespidae is plainly visible, its length about 10 mm., while its breadth is only about 1½; the lower part of the basal nervure is about 6 mm. long, and the first s. m. on cubital nervure is about 3⅘; the second s. m., very faintly indicated, appears triangular, the first t. c. oblique, its upper end most distad, the acute angles formed being of about 45°; the apex of the first discoidal, between the first t. c. and the insertion of the first r. n., is obliquely truncate, — considerably more obliquely than in a modern Vespa examined.

Type. — No. 2026, Mus. Comp. Zoöl. Florissant, Col. (No. 11,741, S. H. Scudder Coll.). This is the largest by far of the Florissant Hymenoptera seen

by me. It gives one the impression, at first, of a large Scoliid, but it is unquestionably a member of the Vespidae.

Palaeovespa scudderi, sp. nov.

Length of anterior wing about 13 mm.; of head, including mandibles, 6; of thorax, 8; of middle femur and trochanter 4½; of middle tibia and tarsus, 7; of first discoidal cell, 7; of marginal cell, which ends in a sharp point on costa, 3⅝; eyes deeply emarginate, as usual in Vespa, but contrary to what obtains in the modern species, the part of the eye above the emargination is almost if not quite as large as that below it; mandibles shaped as usual in the genus; the large lateral lobes of prothorax are strongly vertically striate, the striation resembling that found in the same region in species of Myzine and Ammophila; pleura without such striation; head and thorax, dark, doubtless black in life; the middle leg seems to have been black as far as the beginning of the apical third of the femur, or thereabouts, and beyond that yellow or red; apex of first discoidal cell about as in modern Vespa, but narrow; marginal cell much more pointed than in the modern forms, but venation otherwise normal; abdomen missing. Lateral ocellus about 270 μ broad, and 300 from eye; width of marginal cell about 900 μ; of oblique nervure terminating first discoidal, 225 μ.

Type. — No. 2027, Mus. Comp. Zoöl. Florissant, Col. (No. 9065, S. H. Scudder Coll.).

No. 7738, S. H. Scudder Coll., badly preserved, appears to be a second example of *P. scudderi*, as it shows well the striation of the prothoracic lobes; a feature which is not to be seen in any of the specimens of *P. gillettei*, though it may not really be absent. This specimen has the abdomen, and indicates that *P. scudderi* was about 18 mm. long. The hind margins of the last two abdominal segments were broadly light (probably also the two before these), and the light color (no doubt yellow in life) sent a rounded lobe upwards on each side of the last segment, these markings being of the same type as in modern Vespa. The antennae are normal.

Palaeovespa gillettei, sp. nov.

Length about 14½ mm.; of anterior wing about 10 mm., with the nervures more delicate than those of *P. scudderi;* breadth between wings slightly over 4 mm., of abdomen 5; black, with indications on the mesothorax of what appear to have been two longitudinal yellow stripes; venation as in *P. scudderi*, with the same sharply pointed marginal cell; length of first discoidal a little over 5 mm.; width of marginal cell 600 μ. The abdomen is not so broad basally as in modern Vespa; it is nearly parallel-sided, with the broadest part beyond the middle. The species is allied to *P. scudderi*, but smaller in every way, with more delicate venation.

Type. — No. 2028, Mus. Comp. Zoöl. Florissant, Col. (No. 16,325, S. H. Scudder Coll.). No. 2029, M. C. Z. (No. 11,920, S. H. Scudder Coll.), No. 5986, S. H. Scudder Coll., and No. 2030, M. C. Z. (No. 14,305, S. H. Scudder Coll.,) are also Palaeovespa, and presumably the present species, but they do not show the venation so well. The first two show very distinctly

two light lines or narrow bars on mesothorax, not reaching the anterior or posterior margins, and 5986 also shows a narrow light anterolateral margin, probably really on the prothorax, as is common in living forms. The antennae appear to be as in Vespa. Nos. 2031, 2032, M. C. Z. (Nos. 18,382 and 7868, S. H. Scudder Coll.), are two isolated anterior wings of Palaeovespa. They exhibit a good deal of difference in small details, but are, I think, certainly referable to *P. gillettei*. From them it is possible to ascertain several characters not clearly discernible in the type. Both show a dark cloud in the apical part of the costal cell, such as occurs in modern Vespa. The junction of b. n. to subcostal, which in the type is some 450 μ from base of stigma, is only about 300 from it in No. 18,362, and 345 in No. 8981, but it is difficult to say exactly where the basal n. leaves off, and where the stigma begins, the fusion being gradual. The size is throughout too small for *P. scudderi*. The following measurements are in μ:

	Length of second s. m. on marginal.	Length of third s. m. on marginal.
P. scudderi, Type No. 2027, M. C. Z.	450	825
No. 2032, M. C. Z.	345	675
No. 2031, M. C. Z.	225	675

	First r. n. from beginning of second s. m.	First r. n. (on cubital n.) from second r. n.	Second r. n. from end of second s. m.
P. scudderi, Type No. 2027, M. C .Z.	225	665 ?	375 ?
P. gillettei, Type No. 2028, M. C. Z.	?	?	225 ?
No. 2032, M. C. Z.	150	535	375
No. 2031, M. C. Z.	150	375	300
Vespa (modern)	195	240	750

P. gillettei is named after Professor C. P. Gillette, in recognition of his work on the entomology of Colorado.

EUMENIDAE.

Odynerus palaeophilus, sp. nov.

♀ Rather slender, length 9 mm., anterior wing 8 mm.; black, the wings dusky; first abdominal segment in lateral profile (*i. e.* seen from the side) presenting a curve which is uniform, not abruptly bent at any point, and is equal to about a quarter of a circle; abdomen broad and convex, with the apical part separated, doubtless originally marked off by a suture, as in some living forms; marginal cell very broad, in the form of an elongated triangle, the apex downwards; apex of first discoidal only moderately oblique (much less so than in a modern species compared); second submarginal cell narrowed almost to a point above, its length on marginal being only 60 μ, while its length on cubital nervure is 555 μ; width of marginal cell, 600 μ; width of third s. m. on marginal, 525 μ. It would be easy to misinterpret the venation of this insect (as also of the species of *Palaeovespa*), owing to the folding; but it is easily understood when compared with modern

examples similarly folded. This insect has the closest possible resemblance to a species still living in Colorado, but it differs in the venation in two respects: (1) the second submarginal cell is more contracted above, (2) the cubital nervure is abruptly bent at the end of the first discoidal cell, as in Vespa, whereas in the modern species it is straight.

Type. — No. 2033, Mus. Comp. Zoöl. Florissant, Col. (No. 10,657, S. H. Scudder Coll.)

Odynerus praesepultus, sp. nov.

♀ Black, apparently with two light longitudinal bars on mesothorax; length nearly 11 mm., head and thorax about 4 mm., anterior wing 7 mm.; wings folded, somewhat reddish; flagellum thick, (the end tapering, not clavate,) dark above, light below; abdomen sessile, second segment not swollen, dorsally or ventrally; in lateral profile, the dorsum of abdomen is gently curved, the venter nearly straight, no segment markedly different from the one before it. Stigma large, its width (short diameter) about 200 (this and other measurements in μ); marginal cell subtriangular, 1350 long, about 450 broad, narrowly obliquely truncate, the truncation about 150 broad; tip of marginal cell about level with apex of third s. m.; b. n. inserted at base of stigma, its upper section about 450 long; first s. m. 1425 long; stigma to insertion of first t. c., 450; second s. m. much narrowed above (150 long on marginal), and receiving both recurrent nervures; first r. n. from origin of first t. c., 250 (lower basal corner of second s. m. very acute); distance between insertion of first and second r. n., 300; cubital nervure not at all bent at end of first discoidal; insertion of second r. n. to origin of second t. c., 105; lower margin of third s. m., 600; third s. m. on marginal, 450; insertion of third t. c. to apex of marginal cell, 450.

Type. — No. 2034, Mus., Comp. Zoöl. Florissant, Col. (No. 11,944, S. H. Scudder Coll.). This is readily known from Palaeovespa by (1) marginal cell obliquely truncate at end, the tip not on costa; (2) cubital nervure not at all bent at end of first discoidal, (3) b. n. originating at base of the very large stigma. It appears to be one of the Eumenidae, the venation agreeing with that group better than with the Vespidae. Among the Eumenidae, from the venation and structure of the abdomen, it can go only in Odynerini, and it is referred to Odynerus in the old, broad sense. The modern genera of Odynerini are separated mainly on characters which are not discernible in the fossil.

ICHNEUMONOIDEA.

STEPHANIDAE.

Protostephanus, gen. nov.

Head rounded or subquadrate, rugose or tuberculate; prothorax broad but produced, with a median longitudinal groove, and fine lateral oblique striae; abdomen sessile; hind coxae elongated, about $\frac{2}{3}$ the length of their femora; hind femora moderately stout, not toothed; stigma rather large; costal cell very distinct; terminal part of subcostal nervure, for a distance nearly equal to the length

of the stigma, much thickened and appearing black; marginal cell long and quite narrow; b. n. strongly bent at beginning of cubital nervure; t. m. opposite b. n., the latter very slightly more basad; only one s. m., which is considerably broader than the first discoidal; first r. n. meeting first t. c., which is continued in a straight line with it, making, with the cubital nervure, a large $\times$. This interesting genus differs from those hitherto known by the combination of an elongated prothorax, unarmed hind femora, and sessile abdomen.

Protostephanus ashmeadi, sp. nov.

Length about 9½ mm.; anterior wings clear, with brassy iridescence still showing, their length about 6 mm.; hind coxae transversely striate; hind tibiae claviform, swollen apically, the hind tibiae and tarsi about as long as hind coxae and femora, but the tibiae somewhat longer than the femora; pleura finely striate; measurements in μ: — width of head about 1500; length of thorax anterior to wings about 1200; length of hind coxae about 1200; width of hind tibiae at apex about 450; breadth of hind femora about the same; extension of abdomen beyond apex of hind femora perhaps 1500; breadth of stigma about 180; breadth of marginal cell about 300; length of first (and only) s. m. 975; length of first discoidal, 900; length of the quadrate second discoidal about 795; length of t. m. not quite 300; length of second section of b. n. (bounding first discoidal) about 450.

Type. — No. 2035, Mus. Comp. Zoöl. Florissant, Col. (No. 13913, S. H. Scudder Coll.). Named after Mr. W. H. Ashmead, whose writings were most useful in determining the affinities of the insect.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. L. No. 3.

REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE EASTERN TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM OCTOBER, 1904, TO MARCH, 1905, LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

VI.

MADREPORARIA.

By T. Wayland Vaughan.

With Ten Plates.

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No. 3. — *Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross" from October,* 1904, *to March,* 1905, LIEUT. COMMANDER, L. M. GARRETT, U. S. N., COMMANDING.

VI.

MADREPORARIA. By T. WAYLAND VAUGHAN.[1]

Mr. Alexander Agassiz has submitted to me for determination and report the Madreporaria collected during the "Albatross" Expedition of 1904–1905. The collections are small, and represent only seven localities.

Two species, *Pocillopora lacera* Verrill and *Astrangia haimei* Verrill, were obtained from Taboguilla Island, Bay of Panama, the former at a depth from low tide to 1 fm., the latter between tides.

Three species were obtained in the vicinity of the Galapagos Islands, viz. : —

Madrepora galapagensis, sp. nov., depth 300 fms.
Desmophyllum galapagense[2], sp. nov., depth 300 fms.
Balanophyllia galapagensis, sp. nov., depth 100 fms.

One species, *Bathyactis marenzelleri*, sp. nov., was collected off Callao, Peru, at a depth of 3,209 fms. The same species was obtained at Station 4721, about half way between the Galapagos and Garrett Ridge, at a depth of 2,084 fms., and probably at Station 4732, southwest of Garrett Ridge, at a depth of 2,012 fms.

Two species, *Pocillopora diomedeae* and *Porites paschalensis*, both new species, were collected on the shore of Easter Island.

Five species, a variation of *Pocillopora cespitosa* Dana and four species of Acropora, were obtained at Manga Reva.

[1] The Director of the U. S. Geological Survey has allowed me to prepare this Report as part of my official work.

[2] The name *Desmophyllum galapagensis,* on Plate 1 printed as originally proposed, has been changed to the more correct *D. galapagense.*

The two shore species from Taboguilla are well-known Panamic forms. The two from Easter Island group with species known from the South Pacific and Indian Ocean. The species from Manga Reva belong to the fauna of the Southwestern Pacific and Indian Ocean.

The literature on the deep-sea Madreporaria of the Eastern Pacific is almost nil. Moseley, in his "Deep-Sea Corals" obtained by the "Challenger" Expedition, described a few, and Dr. von Marenzeller has published a report on the "Stein- und Hydro-Korallen" collected off the west coast of Central America to the Galapagos, to the west coast of Mexico, and in the Gulf of California, by the "Albatross" in 1891.[1] He records eight species of Madreporaria, five of which are specifically identified, viz.: —

Desmophyllum cristagalli M. Edw. & H.
Caryophyllia diomedeae von Marenzeller.
Madrepora oculata Linné.
Cladocora arbuscula (Le Sueur).
Bathyactis symmetrica (Pourtalès).

I am able to add four species. There is a considerable quantity of unstudied deep-sea material from the Pacific coast of America in the United States National Museum, but I have not as yet been able to describe it. However, I hope to do so within a short time in connection with monographing the Tertiary coral faunas of the Western United States. The Hawaiian Expedition of the "Albatross," 1902, was fortunate in procuring a considerable collection of deep-sea Madreporaria. I have described that collection for the United States Bureau of Fisheries, and found it very interesting for comparison with the faunas of the Southwestern Pacific and Indian Ocean on one side and that of Western America on the other.

These notes are presented to show the meagerness of our knowledge of the deep-sea Madreporaria of the greater portion of the Pacific Ocean. We do not yet know enough to undertake the discussion of the broader problems of geographic distribution. The collection made by the "Albatross" in 1904–1905, though small, is interesting and important, as it makes a distinct addition to our knowledge of Pacific deep-sea Madreporaria.

The Panamic specimens are omitted from the following discussion of the species.

[1] Bull. Mus. Comp. Zoöl., **43**, p. 75–87, 3 pls., 1904.

Desmophyllum galapagense, sp. nov.

Plate 1, figs. 1–1b.

Corallum curved, attached by an expanded base; transverse outline of calice, elliptical.

Measurements: height, ·15 mm.; diameter immediately above basal expansion, 2.5 mm.; greater diameter of calice, 6.75 mm., lesser, 6 mm.

The corallum wall is very thin, its outside is polished and glossy, but shows minute transverse lines of growth that are parallel to dentations on its upper edge which correspond in position with the septa.

Septa thin, in four complete cycles, primaries and secondaries of equal size, with exsert margins, about 1.5 mm., tertiaries shorter, quaternaries still smaller and may be rudimentary. The septal faces granulated, granulations small, showing arrangement parallel to the septal margin and also in linear series.

Calicular fossa very deep and narrow. No columella.

Locality: — Station 4642, southeast face of Galapagos Islands, 5 miles from southeast end of Hood Island; depth, 300 fms.; bottom, broken shells and Globigerina; temperature of the bottom, 48.6° F. The specimen grew attached to *Madrepora galapagensis*, sp. nov.

Remarks: — *Desmophyllum galapagense* is close to *D. alabastrum* Alcock, but the latter species has the third and fourth cycles of septa buried "in the depths of the cup where at first they escape notice." It is very close to *D. eburneum* Moseley, and may ultimately be combined with that species, it differs from the latter, however, by the entire absence of costae, and none of the primary septa bend outward beyond the margin of the calice.

Madrepora galapagensis, sp. nov.

Plate 1, fig. 2; plate 2, figs. 1–1b.

Corallum in its basal portion thick and compact; branches anastomosing. The colonies evidently attain considerable size. The terminal branchlets are stout, rather short, with thick bases. One branchlet measures 20 mm. in length, 7 mm. in diameter at the base, terminal calice 4.5 mm. in diameter. Some branchlets are shorter, others are longer, and the terminal calice may not have so great a diameter, but the branchlets are constantly relatively thick.

The calices on the branches are usually dichotomous in arrangement, occasionally there is opposite gemmation in a plane at right angles to the plane passing through the middle of the dichotomous calices. On the older portions of the corallum the coenenchyma is very highly developed and there is no definite calicular arrangement.

The fully developed terminal calices are about 4.5 mm. tall, and about 4 mm. in diameter measured between the thecal summits; 4.5 mm. is probably the maximum calicular diameter on a branchlet. On the basal portion of the corallum the calices are as much as 10 mm. apart, and range in diameter from 2.5 to 3.5 mm. in diameter. They are deep, even exceeding 3 mm. The elevation of the calicular

margins is variable, ranging from 1 mm., or even less, to 5 mm. At and just below the calicular margins are costae corresponding to the primary and secondary septa, they usually are not continued far down the outside of the corallite wall.

The coenenchyma is highly developed, absolutely solid, its surface striate, or checkered by superficial canals.

Septa in three complete cycles, the primaries are exsert between .5 and 1 mm., the secondaries less prominent, the tertiaries with scarcely elevated margins. The inner margins descend abruptly, those of the first two cycles extend to the axis, and may or may not form a weak, false columella. The septal faces are striate and granulate, septal edges entire.

The corallite cavities are solidly filled below by stereoplasm.

Locality: — Station 4642, southeast face of the Galapagos Islands, 5 miles from southeast end of Hood Island; depth, 300 fms; bottom, broken shells and Globigerina; temperature of the bottom, 48.6° F.

Remarks: — This species belongs near *Madrepora oculata* (Linné) but differs in its shorter, relatively thicker branches, and its more prominent and deeper calices.

Pocillopora cespitosa Dana var.

Plate 3, figs. 1–1b.

1846. *Pocillopora cespitosa* Dana, Zooph. Wilkes Expl. Exped., p. 525, plate 49, figs. 5, 5*a*.
1846. *Pocillopora brevicornis* (pars) Dana, Zooph. Wilkes Expl. Exped., p. 526.
1860. *Pocillopora cespitosa* Milne Edwards, Hist. nat. Corall., **3**, p. 303.
1869. *Pocillopora caespitosa* Verrill, Proc. Essex Inst., **6**, p. 91.
1886. *Pocillopora cespitosa* Quelch, Reef Corals, "Challenger" Rept., p. 66.
1901. *Pocillopora caespitosa* Studer, Zool. Jahrb. Syst., **40**, p. 399.

One specimen was obtained. It is a clump 8 cm. tall, 10.5 cm. long, and about 8.8 cm. wide. It is composed of rather crowded, compressed branches, that bear verruciform branchlets. In form it resembles the stylophoroid variety of the species found in the Hawaiian Islands. The septa and columella are distinct, especially on the basal portion of the corallum, where the latter is often styliform.

For a description of the variations of this species, my report on the Hawaiian Madreporaria, U. S. Bureau of Fisheries Bulletin, should be consulted.

Locality: — Motus reef flats, Manga Reva, Paumotus.

Pocillopora diomedeae, sp. nov.

Plate 2, figs. 2, 2a; plate 6, fig. 1.

Corallum composed of short, subterete or compressed elliptical, or wide, flattened blunt branches, the ends sometimes incrassate or subclavate. Seven broken branches were obtained, probably all belonging to the same colony, and because of the darker, reddish color of the lower ends the total length is probably represented.

Specimen.	Length.	Diameter of Lower End.		Diameter of Upper End.		Shape of Upper End.
		Greater.	Lesser.	Greater.	Lesser.	
1	46 mm.	17 mm.	11 mm.	7 mm.	5 mm.	Obtuse.
2	45	14	12.5	13	9	Obtuse, subclavate.
3	55	11	10	21	10	Obtuse, incrassate.
4[1]	67	15	12	14	10	Obtuse.
5	59	15	13.5	22	14	Obtuse.
6	69	22	17.5	32.5	16.5	Obtuse, bifurcation 22 mm. below upper end.
7	66	30	12	42.5 38.5	12 16	Obtuse, bifurcation 36.5 mm. below upper end, measurements given for each branch.

[1] The specimen figured.

Verrucae obsolete or irregular in development. They may bear from three to five calices, scarcely elevated above the usual level of the surface of the branch, or may be as much as 3.5 mm. tall and covered by as many as 20 calices. The larger verrucae are appressed, greater diameter 6 mm., lesser, 3.5, with the apices distally directed. They are better developed along the more compressed edges than on the flatter sides. Their distance apart is too variable to possess any systematic value.

Calices with slightly elevated margins; deep over the whole surface, about 1 mm. near the lower end. The apical ones are separated by narrow, acute walls and have a maximum diameter of 1.5 mm.; those on the sides, about 30 mm. below the apex, are 1 mm. in diameter and are separated by walls from .5 to .75 mm. thick; those near the base (65 mm. from the apex), are about .75 mm. in diameter and are separated by an equivalent thickness of coenenchyma. The calices on the verrucae are about 1 mm. in diameter and are closer together than on the adjacent portions of the side of the corallum.

Septa are indistinct in the apical calices, distinct in practically all others, but somewhat irregular in development, usually best developed near the lower end of the branch. The number is twelve, two complete cycles, with occasional members of the third. A varying number, from one to six, are much thickened and have very exsert edges; but all, excepting one or both of the directives, are narrow, rendering the fusion to the columella invisible from above. The inner margins are spinulose. The columella is usually well developed, arises deep down in the

calice; it is rather thick and terminates in one or several prominent ascending spines.

The coenenchyma is usually very dense, its surface beset with isolated, erect, compressed, truncated spinules. A circle of more prominent spinules surrounds each calicular cavity, those intervening usually less prominent.

The corallites cavities often solidly filled with internal deposit, rendering the corallum very dense; tabulae, when present, from .5 to 1 mm. apart.

Locality: — Shore, Easter Island.

Remarks: — This is the most distinctly characterized species of Pocillopora that has come under my observation, as I know no other that is really very similar. The thick branched or frondose species in which the septa are well developed and the columella prominent are *P. modumanensis* Vaughan (Hawaiian Islands), *P. ligulata* Dana, *P. plicata* Dana, *P. coronata* Gardiner, *P. eydouxi* M. Edw. and H. and *P. elongata* Dana. *P. rugosa* Gardiner has in the lower calices a slender very prominent columella, but the septa are very indistinct; *P. capitata* Verrill, from Panama, in some of its variations appears to have distinct septa and a styloid columella. The only species whose name is listed above with which *P. diomedeae* need be compared is *P. elongata* Dana. *P. elongata* has longer, thicker branches, more uniformly developed and uniformly distributed verrucae, the columella (judging from Verrill's redescription of the type)[1] is not so thick, and the texture much more porous. It is very probable that the exsert margins of a portion of the septa in *P. diomedeae* and the compressed, truncated granulations of its coenenchyma constitute additional differences.

Bathyactis marenzelleri, sp. nov.

Plate 4, Figs. 1–1 b.

Base of the corallum circular, 22.5 mm. in diameter, almost flat, slightly concave in the middle. The wall is extremely thin and translucent. Thin, slightly wavy costae correspond to all septa, but become obsolete on the central portion of the base; those corresponding to the last cycle smaller and more irregular in development. The costal edges are irregularly, sometimes coarsely, dentate.

The calice is superficial, almost everted. Septa extremely thin, in four complete cycles, forming six septal groups, one group between each pair of primaries. The tertiaries fuse by a kind of calcareous membrane to the included secondary, and the quaternaries fuse nearer the wall by their inner margins to the included tertiary. There is an occasional rudiment of a fifth cycle. The margins of the primaries are very tall, projecting 9 mm. above the base, the secondaries are almost as prominent as the primaries, the tertiaries are slightly less prominent than the secondaries, the quaternaries are decidedly less prominent than the other septa. The outer portion of the septal margins is irregularly lacerate, the inner half between the columella and the periphery possesses from three to four distant, tall, erect, thin, spines. Septal faces without granulations, fluted, with distant carinae, some of which connect below with synapticula. These carinae vary from

[1] Proc. Essex Inst., 6, p 99, 1869.

somewhat less than 1 mm. to almost 2 mm. apart. From three to five thin, membraniform synapticula, formed by the basal fusion of opposed carinae, occur in each interseptal loculus.

The inner ends of the septa are united by a calcareous membrane, through which small, thin, spinose, septal processes project. The diameter of the columella platform is 5 mm.

Localities: — (*Type*) — Station 4721 between Galapagos and Barrett Ridge ; depth 2,084 fms. ; bottom, light brown Globigerina ooze, sponge, spicules, diatoms, a few Radiolaria; thermometer failed to register on the bottom; 1 specimen.

Station 4670 western edge of Milne Edwards Deep off Callao ; depth 3,209 fms. ; bottom, soft, light brown mud ; temperature of the bottom, 35.4° F. ; 3 specimens, partially decalcified, two were cleaned by boiling in a solution of caustic potash, and were easily identifiable.

A specimen of Bathyactis, which had been decalcified, was dredged at station 4732, between Barrett Ridge and Manga Reva, at a depth of 2,012 fms. This specimen is not specifically identifiable, but probably belongs to *B. marenzelleri.* Bottom, light gray, Globigerina ooze, sharks' teeth, and ear bones, manganese nodules, very few diatoms and radiolaria, sponge spicules ; temperature of the bottom, 34.8° F.

Remarks: — This species according to Alcock's synopsis of the species of Bathyactis [1] obtained by the " Siboga " is nearest to *B. symmetrica* (Pourtalès), as it possesses no pali and only four cycles of septa. But it differs markedly from that species. The shape of the septa and the character of their margins are entirely different — the great elevation of the septal margins and their peculiar laceration are very striking. *B. sibogae* Alcock is similar to *B. symmetrica*, differing by possessing five, instead of four, cycles of septa. *B. stephana* Alcock possesses elevated septal margins, but the base of the corallum is concave and there are five cycles of septa. Alcock's figure [2] of the last named species indicates that its septal margins are peripherally narrow or excavated, and that they are elevated near the calicular fossa, the reverse of the condition in *B. marenzelleri*. *B. hawaiiensis* Vaughan has a general similarity in form, but it possesses five cycles of septa, its septal margins are not so lacerate and the carinae on the septal faces are much more crowded, and bear spinose granulations. It therefore seems that *B. marenzelleri* is decidedly different from any other hitherto discovered species of the genus.

Balanophyllia galapagensis, sp. nov.

Plate 4, Figs. 2-2 b.

Corallum elongate, slightly curved, with broadly elliptical transverse outline. The lower end is broken and the calicular margin is somewhat, but not greatly, damaged. The following are the measurements: length, 20.5 mm.; lower end,

[1] Deep-Sea Madreporaria of the Siboga Exped., p. 37.

[2] Investigator Deep-Sea Madreporaria, plate 3, fig. 5*a*.

greater diameter, 6.5 mm., lesser, 5.5 mm.; upper end, greater diameter, 7 mm., lesser, 5.5 mm.

The upper edge of the wall is rather thin, but below it is very much thickened — there is so much internal deposit that practically the whole of the internal structures are obliterated. An incomplete, pellicular epitheca extends to within 5 mm. of the calicular edge. The wall is costate, the costae are perforated, low, subacute, and granulated on the edge, with narrow, perforated intercostal furrows. Every fourth costa is slightly larger than those intervening.

The septa are in four complete cycles, the primaries and secondaries are equal and extend directly to the columella, the tertiaries are included between the distally diverging quaternaries, which fuse before the tertiaries and are connected by a plate with the columella. The primaries, secondaries, and quaternaries are thick, the tertiaries are decidedly thinner. The septal margins are only slightly exsert, arched above, the inner margin falling perpendicularly to the periphery of the columella. The septal faces are densely beset with obtuse or truncated granulations, which, especially near the septal margins, show serial arrangement.

The columella is large and prominent, greater diameter, 3.5 mm., half the greater diameter of the calice; lesser diameter, about 2 mm., one-third the lesser diameter of the calice. Its upper surface is slightly domed, rising above the level of the septal fusion to its sides. It is composed of thin curled flakes that are united one to another by synapticula.

The calicular fossa is shallow, about 1.5 mm. its maximum depth.

Locality: — Station 4643, southeast of the Galapagos Islands, about 4½ miles west by south from the west end of Hood Island; depth, 100 fms.; bottom, broken shells and Globigerina; temperature of the bottom, 67.2°.

Remarks: — This species is so peculiar that I do not know of any other one with which to compare it. It presents only generic similarity to *B. elegans* Verrill, from the Pacific coast of the United States, and it is not closely related to any of the Hawaiian species of Balanophyllia known to me. Probably *B.* (*Thecopsammia*) *gemma* Moseley is the most similar, but *B. galapagensis* is much more elongate, and differs in the details of the septal arrangement.

ACROPORA Oken.

Four specimens belonging to this genus were obtained from Manga Reva. One specimen is incrusted with nullipores and is not in condition for positive specific determination, it, however, is closely related to *Acropora* (*Tylostoma*) *humilis* (Dana) and may belong to that species.

It is with a feeling of positive regret that I describe two supposedly new species of this genus, but I have been utterly unable to refer them to any described species.

Acropora mangarevensis, sp. nov.

Plate 6, Fig. 2; Plate 8, Fig. 1.

Corallum rising from a stout pedicel, 61 by 35 mm. in diameter, irregularly vasiform, fusion of the branches imperfect near the periphery. Height of specimen, 20 cm.; diameter of vase, 24.5 cm.; depth of vase, 7.7 cm.

The upper surface is occupied by short erect branches, which are conical in shape in the central portion. One of the central branches is 14 mm. in diameter at the base, and 14 mm. in height. Outside the central area, as the wall of the vase slopes rather steeply, the outer angle between a branch and the branch from which it rises or the common wall, is acute. The maximum length of the free portion of a branch is 27 mm.; the branches are radially compressed, diameter along a radius 12 mm. (a little more than 1 cm.), perpendicular to a radius 1 cm. or slightly less. Apices from 1 to 2 cm. apart. Nearly all the branches bear branchlets or proliferous calices.

Calices on the expansion below the pedicel immersed, from the base of the pedicel to the upper edge the immersed calices become progressively fewer, while slightly protuberant ones become more numerous. Apertures labellate or circular; the inner wall may or may not be elevated. The maximum height of these external corallites is about 2 mm.; diameter of base about 2 mm.; calicular diameter about 2 mm.; diameter of aperture about .75 mm. The corallites decrease in diameter toward the calices very slightly. Corallite wall costate, perforate. The corallites of the upper surface are immersed between the bases of the branches, about 1 mm. in diameter; on the branches there are immersed corallites, the other corallites may be labellate with only the outer wall developed, nariform or tall and proliferous. The diameter of the calicular aperture is about .75 mm., one of the long corallites is 3.5 mm. in length. The apical corallites are frequently aborted, when present, 1.75 mm. is probably an average diameter, projecting about 1 mm. The corallite walls are acutely costate, and often imperforate except near the upper edge.

Two cycles of septa are uniformly well developed, the directives more pronounced.

Coenenchyma echinulately striate, perforate, but with a tendency to compactness.

Locality: — Manga Reva.

Remarks: —I do not know of any other species that closely resembles this one; there is a superficial resemblance to all other vasiform, or palmate Acroporae, but there the resemblance, so far as my knowledge goes, stops.

Acropora diomedeae, sp. nov.

Plate 7, Figs. 1, 1 a; Plate 8, Figs. 2, 3.

Corallum vasiform, with a pedicellate base. The branches fusing completely except near the periphery.

Height, 20.7 cm.; diameter of vase, 32 cm.

The upper surface is occupied by short erect, or sub-erect branches that rise from a common plateau. They are irregular in height and diameter, between 3 and 3.5 cm. tall near the periphery, and 8 mm. in diameter at the base; at the center the height is about 2.5 cm., diameter at base may be as little as 7 mm. The distance apart of the bases is usually less than 1 cm., 6 to 8 mm. Very few of the branches are single, finger-like processes, most of them bear less developed lateral branchlets or proliferous calices.

Calices of the lower surface immersed near the lower edge of the pedicel; some, but a very few, are immersed on the bowl portion of the vase. The other calices slightly elevated, appressed, with distally directed, circular apertures. The corallites are

tubular, with complete inner walls. The length varies up to 5 mm., aperture above the surface up to 2.5 mm.; calicular diameter of the corallites about 1 mm., basal 1.5 mm. Walls perforate, sharply costate. The calices of the upper surface represent several types: (a) those between the bases of the branches are immersed; (b) on the branches; apical corallites tubular, 1.5 mm. in diameter, projecting as much; calicular aperture .75 mm., walls sharply costate and perforate; the lateral calices are of at least three kinds, elongated, proliferous calices that may develop branchlets; ascending calices with very oblique apertures, height may be as much as 4 mm., diameter about 1 mm. The inner wall is rarely or never so well developed as the outer, but it is rarely absent; the outer lips of the calices are sometimes curved inward. In addition to the proliferous and simple ascending lateral calices, there are immersed or subimmersed calices, which become more numerous towards the base of the branch.

Septa in the apical corallites, six; in the lateral corallites of the branches the directives are distinct, the others are usually rudimentary. The septa of the under surface are very variable in development. There may be from less than six to two complete cycles.

Coenenchyma porous and echinulate.

Locality: — Manga Reva.

Remark: — This is the only vasiform Acropora whose calices have only six septa known to me.

Acropora aff. canaliculata (Klunzinger).

Plate 5, Figs. 1–1b.

1879. *Madrepora canaliculata* Klunzinger, Korallenth. Roth. Meer. **2**, p. 12, Plate 7, Fig. 3, Plate 4, Fig. 10, Plate 9, Fig. 8.

I have been unable to decide positively to what species a piece of a corallum from Manga Reva should be referred. It belongs to Brook's subgenus Tylopora, to Section C of that subgenus, and to subdivision *b* of Section C. It groups with *A. seriata*, *A. pyramidalis*, and *A. canaliculata*. I have considered it nearer to *A. canaliculata* because of practically complete agreement with Klunzinger's figures of the general habit of the corallum, and the detail of a single branch, Plate 7, Fig. 3, Plate 4, Fig. 10. As three figures are given of the Manga Reva specimen, a detailed description is not necessary. The branchlets are rather thicker than Klunzinger's figures indicate, and the apical corallite is 4 mm. in maximum diameter. The radial calices are of three kinds; some are sunken, others in which the upper wall is wanting, and still others with a developed upper wall, among the last are occasionally some that are subtubular. The tubular calices are slightly dilated at the mouth. No calices with a longitudinal slit in the upper wall, such as is represented in Klunzinger's Plate 9, fig. 8 c–d, were seen;

fig. 8 e–f represent the usual condition very well. I wish to call attention to four possible differences between the Manga Reva specimen and *A. canaliculata:* — 1. the somewhat thicker branches; 2. its slightly smaller apical corallites; 3. the absence of radial corallites with slit upper walls; 4. the occurrence of a few calices that are slightly dilated at the mouth. Of these differences, No. 3 can probably be entirely discarded, as the usual form of the calices corresponds to that for *A. canaliculata.* The other differences are in degree. I therefore think that the Manga Reva is *A. canaliculata,* but with so little material a positive identification is hazardous.

Locality: — Outer edge, Motus reef flats, Manga Reva.

Porites paschalensis, sp. nov.

Plates 9, 10.

Corallum attached by a large base, increasing in diameter as it grows upward, upper surface flat, with rather wide shallow furrows and some circumscribed depressions. Height of largest specimen 15 cm., greatest distance across the top, 22 cm. Plate 9 gives two views, natural size, of a smaller specimen, and shows the mode of growth.

Calices polygonal, varying greatly in size; on the more elevated portions of the upper surface they may be fully 2 mm. in diameter, while in neighboring depressions the diameter may be scarcely 1 mm.; on the sides 2 mm. is the maximum diameter. The variation in depth is considerable, on the upper surface relatively deep, between .5 and .75 mm.; on the sides, shallow.

The walls between neighboring calices are thin, elevated, with numerous perforations between the synapticula joining the component trabeculae; the upper edge is spinulose, and with spinules more numerous than the septa, the spinules irregularly granulated. On the sides of the corallum, within the wall and at a lower level is a fairly regular ring of thick synapticula, above each of which is a frosted granulation. The trabeculae forming this ring are what Bernard calls the "wall trabeculae."[1] There is intervening between the mural trabeculae and the pali usually a ring of elevated, pointed spines, Bernard's "septal granules," which equal in height the mural granules and exceed that of the pali. The pali are distinct low points. The columella is a compressed tubercle, situated in a depression.

The dorsal, solitary, directive and the lateral pairs bear pali as is usual in the genus. The members of the ventral triplet are not intimately united, although their ends are joined by the palar ring. The middle septum of the triplet may bear a palus, but usually in this group the septal granules simulate pali and seem to form part of the palar ring.

The preceding description of the wall and septa is based upon the calices on the sides of the corallum; on the top, the wall ridge is decidedly

[1] Cat. Madrep. Corals, Brit. Mus. 5. The Genus Porites, p. 14, 273, 1905.

more elevated, but the septa, although distinct and arranged as on the sides, do not have the various trabecular elements so clearly differentiated, the latter, however, are the same in number and arrangement on both sides and top.

Locality: — Easter Island.

Remarks: — This species belongs in division "B" of Bernard's "Analysis and distribution of types of calicles," "Forms in which one ring of extra, intervening, or costal trabeculae appears typically in the walls."

There are four forms in Bernard's Catalogue of Porites to which the one under consideration is closely related, they are:

1. P. Fiji Islands (24) 4, p. 46.
2. P. Ellice Islands (17) 8, p. 70.
3. P. Ellice Islands (17) 9, p. 72.
4. P. Ellice Islands (17) 10, p. 73.

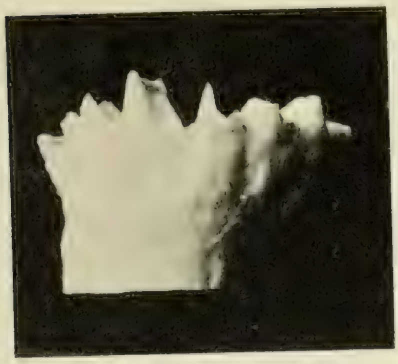
The calices of the last three are somewhat smaller than in the Easter Island form; the resemblance to the first is extremely close, but its skeleton seems denser. As none of the forms with which comparison is made have been named specifically, the validity of *P. paschalensis* is not affected should it prove identical with one of them.

EXPLANATION OF PLATES.

PLATE 1.

FIGS. 1, 1*a*, 1*b*. Desmophyllum galapagense, sp. nov., p. 63. Fig. 1, upright view of corallum, height, 15 mm.; fig. 1*a*, calicular view, greater diameter, 6.75 mm.; fig. 1, view of the edge of the wall, × 4.

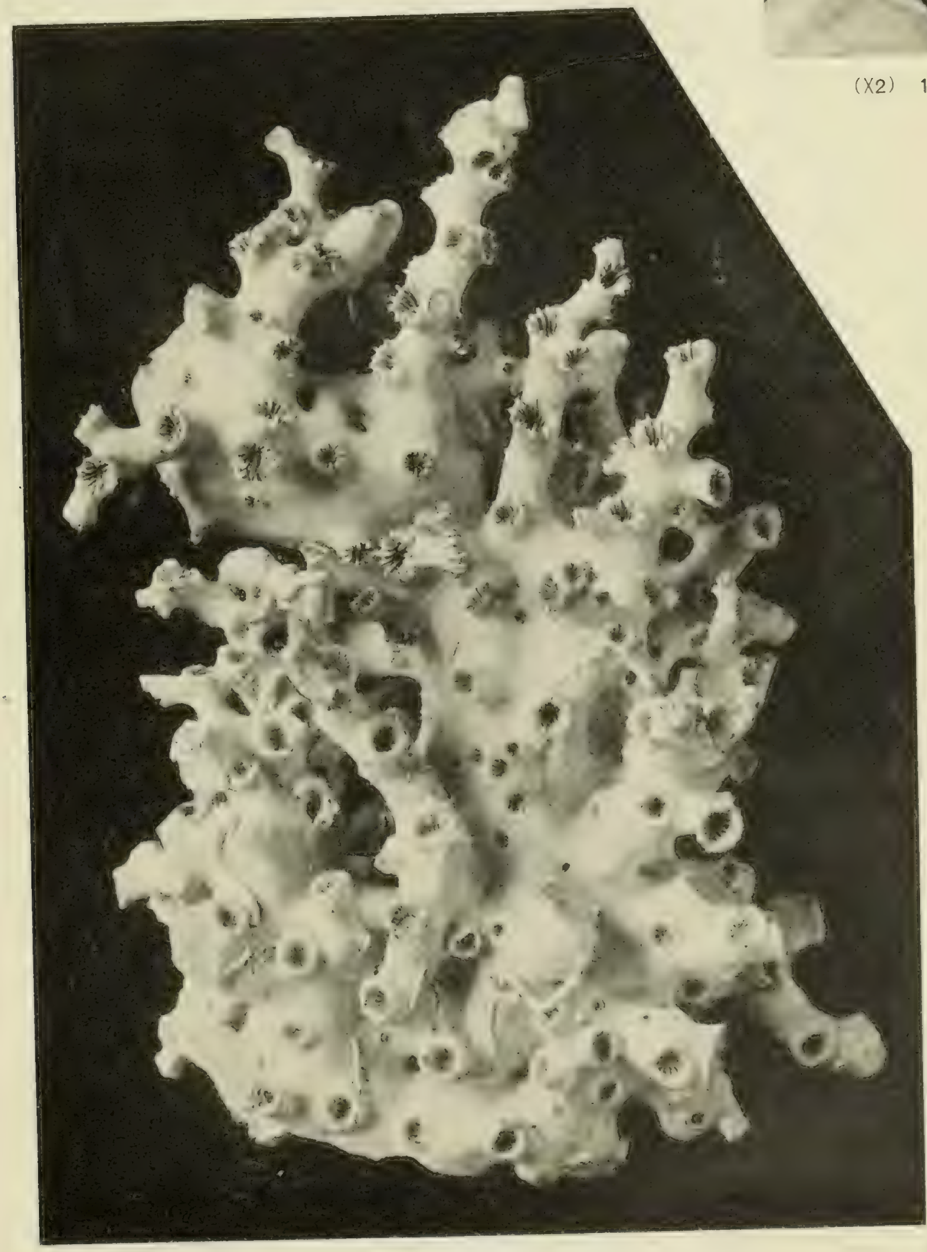
FIG. 2. Madrepora galapagensis, sp. nov., p. 63. General view of a corallum, natural size.



(X4) 1b

(X3) 1a

(X2) 1



2

FIGS. 1-1B. DESMOPHYLLUM GALAPAGENSIS.

FIG. 2. MADREPORA GALAPAGENSIS.

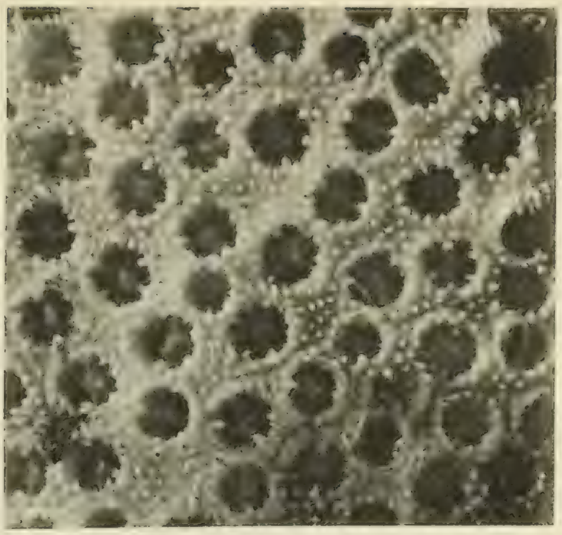
HELIOTYPE CO., BOSTON.

PLATE 2.

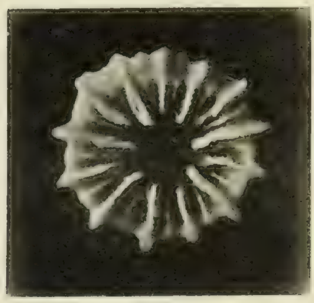
Figs. 1, 1*a*, 1*b*. Madrepora galapagensis, sp. nov., p. 63. Fig. 1, view of a single branch, natural size; fig. 1*a*, the same branch, × 2; fig. 1*b*, a calice, × 4.

Figs. 2, 2*a*. Pocillopora diomedeae, sp. nov., p. 65. Fig. 2, general view of a branch, natural size; fig. 2*a*, calices, enlarged about 8 times.

1

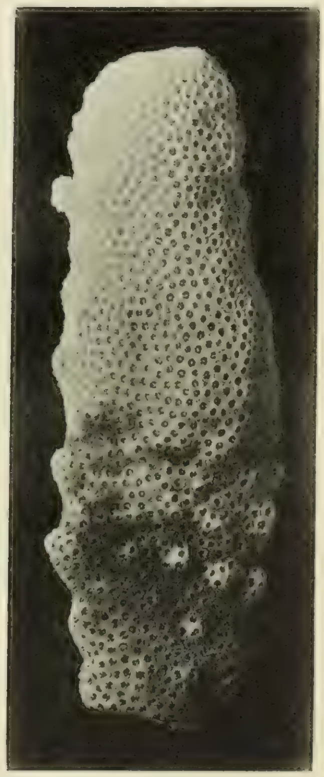


2a



(X4) 1b

1a



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FIGS. 1-1B. MADREPORA GALAPAGENSIS.

FIGS. 2-2A. POCILLOPORA DIOMEDEAE.

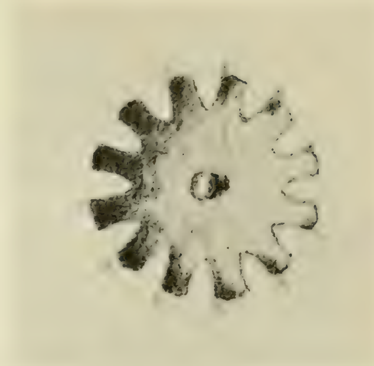
HELIOTYPE CO., BOSTON.

PLATE 3.

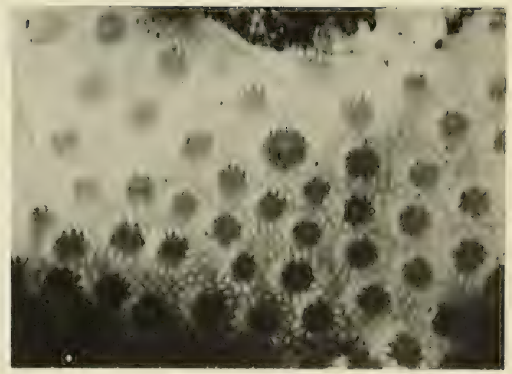
Pocillopora cespitosa Dana var., p. 64.

FIG. 1. General view of the corallum, natural size; fig. 1*a*, calices enlarged about 8 times; fig. 1*b*, a single calice more enlarged, rendered somewhat diagrammatically.

1



1b



1a

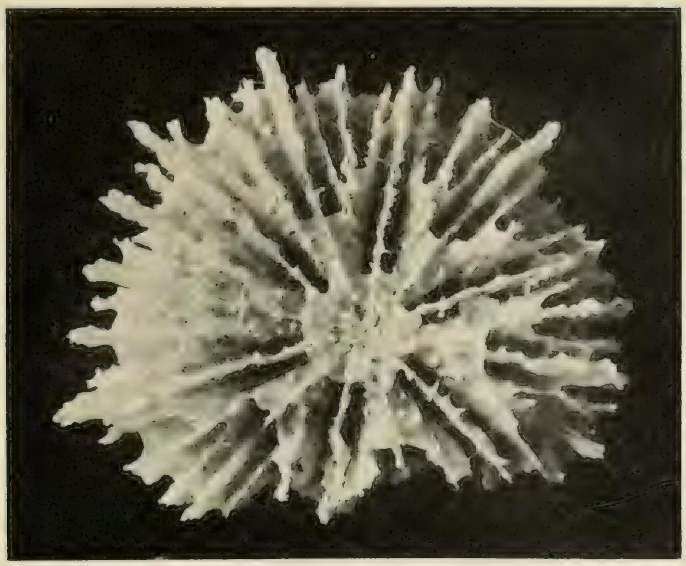
POCILLOPORA CESPITOSA, VAR.

HELIOTYPE CO., BOSTON.

PLATE 4.

Figs. 1, 1*a*, 1*b*. Bathyactis marenzelleri, sp. nov. p. 66. Fig. 1, calicular view, $\times$ 2; fig. 1*a*, basal view, $\times$ 2; fig. 1*b*, side view of a septum, $\times$ 4.

Figs. 2, 2*a*, 2*b*. Balanophyllia galapagensis, sp. nov., p. 67. Fig. 2, upright view of corallum, $\times$ 2; fig. 2*a*, calicular view, $\times$ 3; fig. 2*b*, costae, $\times$ 4.



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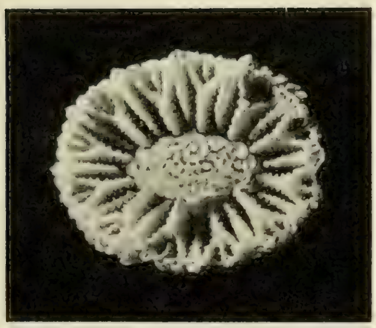
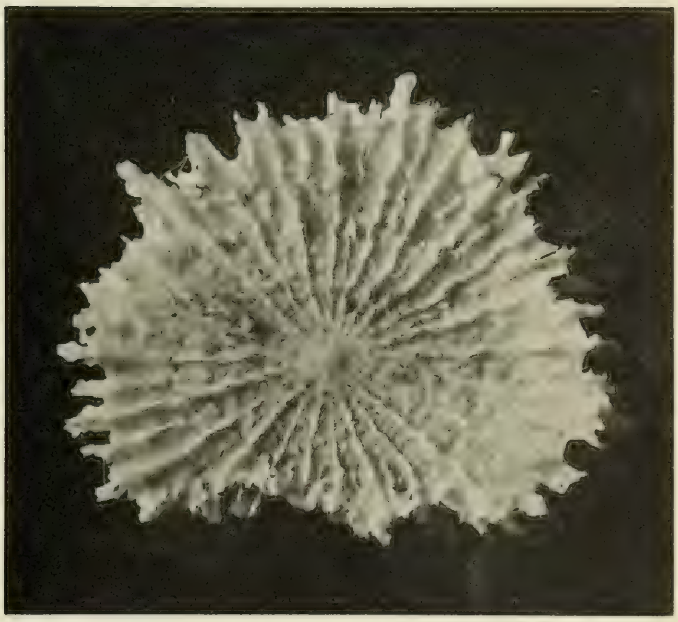
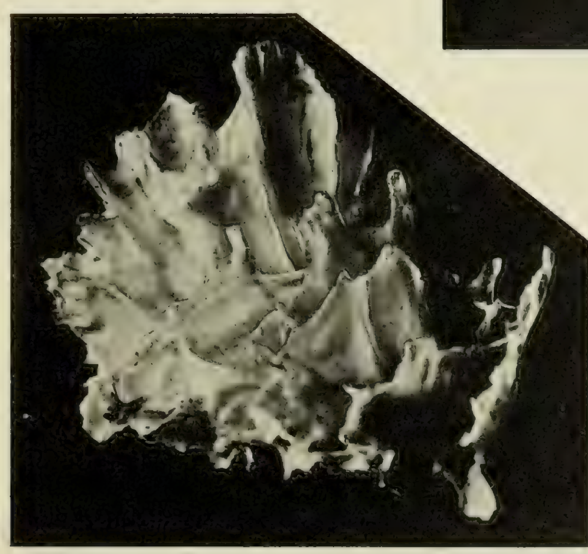


2a



1a



1b

2b

FIGS. 1-1B. BATHYACTIS MARENZELLERI.

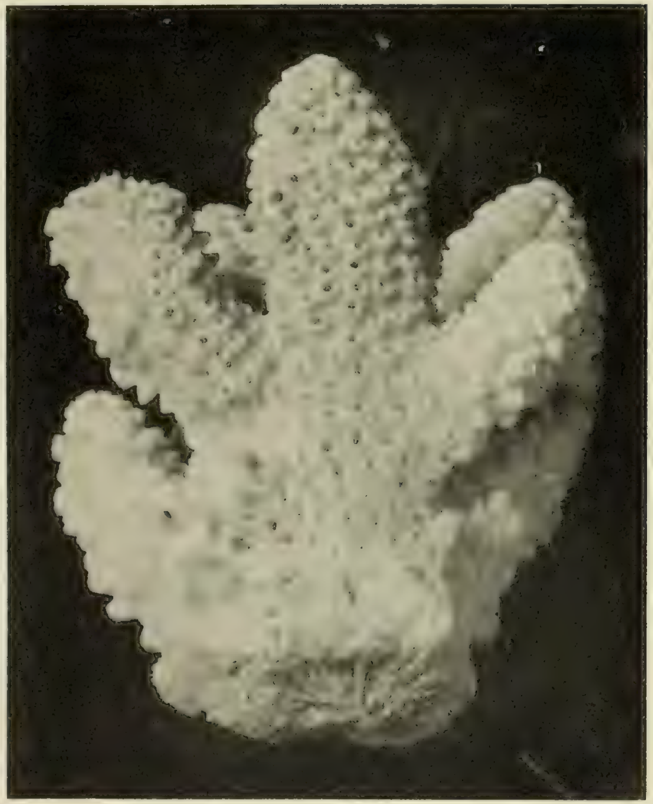
FIGS. 2-2B. BALANOPHYLLIA GALAPAGENSIS.

HELIOTYPE CO., BOSTON.

PLATE 5.

Acropora aff. canaliculata (Klunzinger), p. 70.

FIGS. 1, 1*a*. Two general views of the corallum, natural size; fig. 1, apical corallite, enlarged about 3 times.



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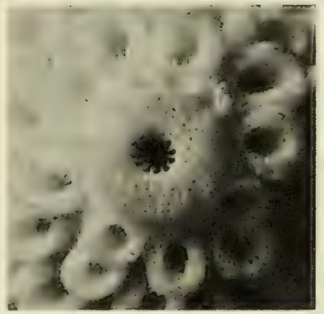
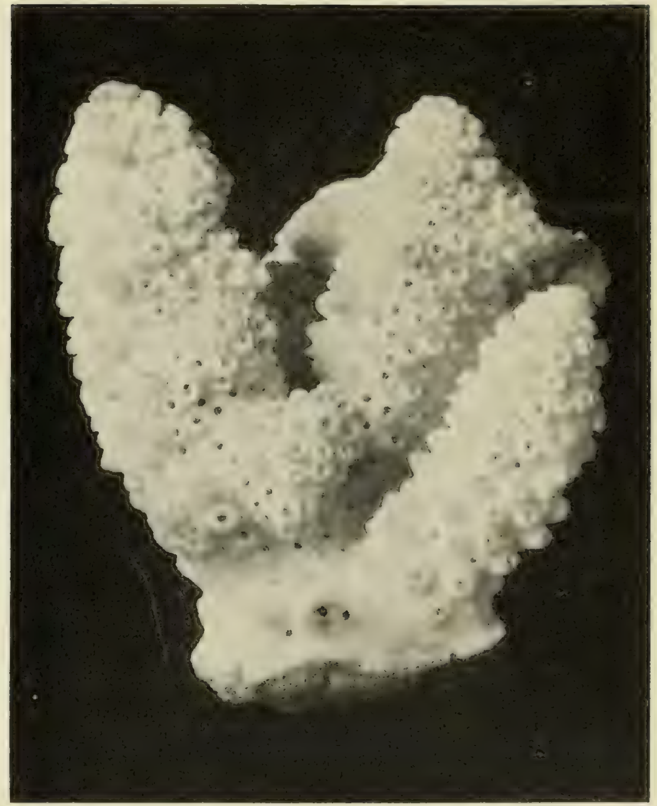


(X3) 1b



1a

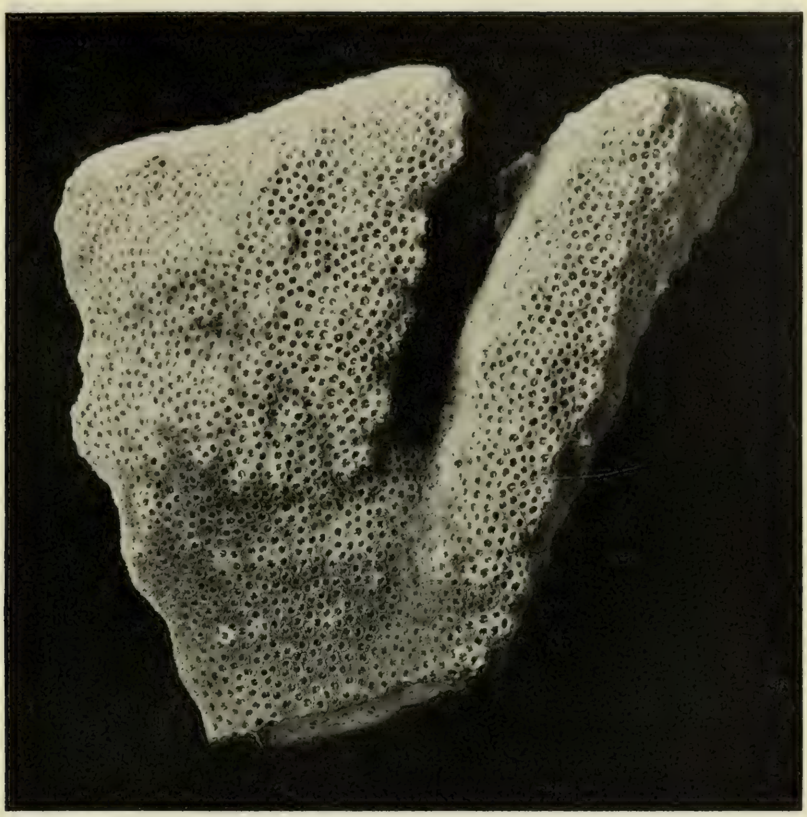
ACROPORA AFF. A. CANALICULATA.

HELIOTYPE CO., BOSTON

PLATE 6.

FIG. 1. Pocillopora diomedeae, sp. nov., p. 65. General view of a bifurcated branch, natural size.

FIG. 2. Acropora mangarevensis, sp. nov., p. 68. Upright view of a corallum, $\frac{1}{3}$ natural size.



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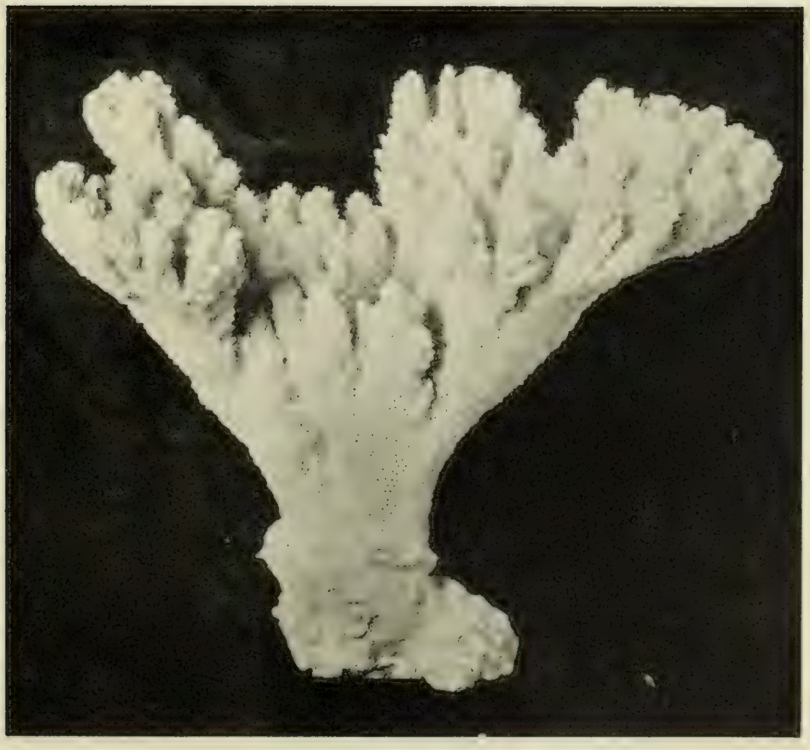


2

FIG 1. POCILLOPORA DIOMEDEAE.

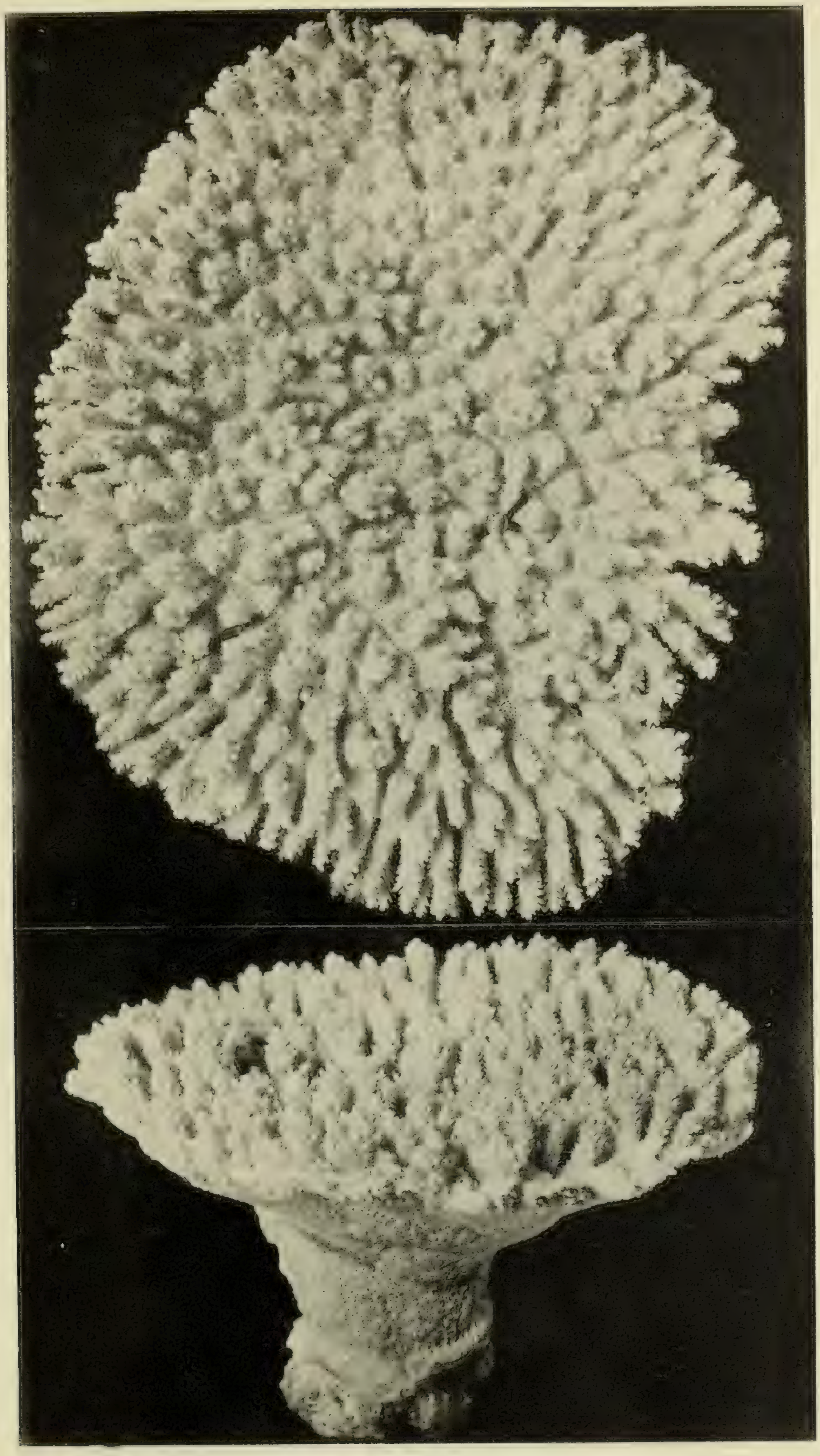
FIG. 2. ACROPORA MANGAREVENSIS.

HELIOTYPE CO., BOSTON.

PLATE 7.

Acropora diomedeae, sp. nov., p. 69.

FIG. 1. Upper surface of corallum, $\frac{1}{8}$ natural size; fig. 1*a*, upright view of corallum, $\frac{1}{8}$ natural size.



1

1a

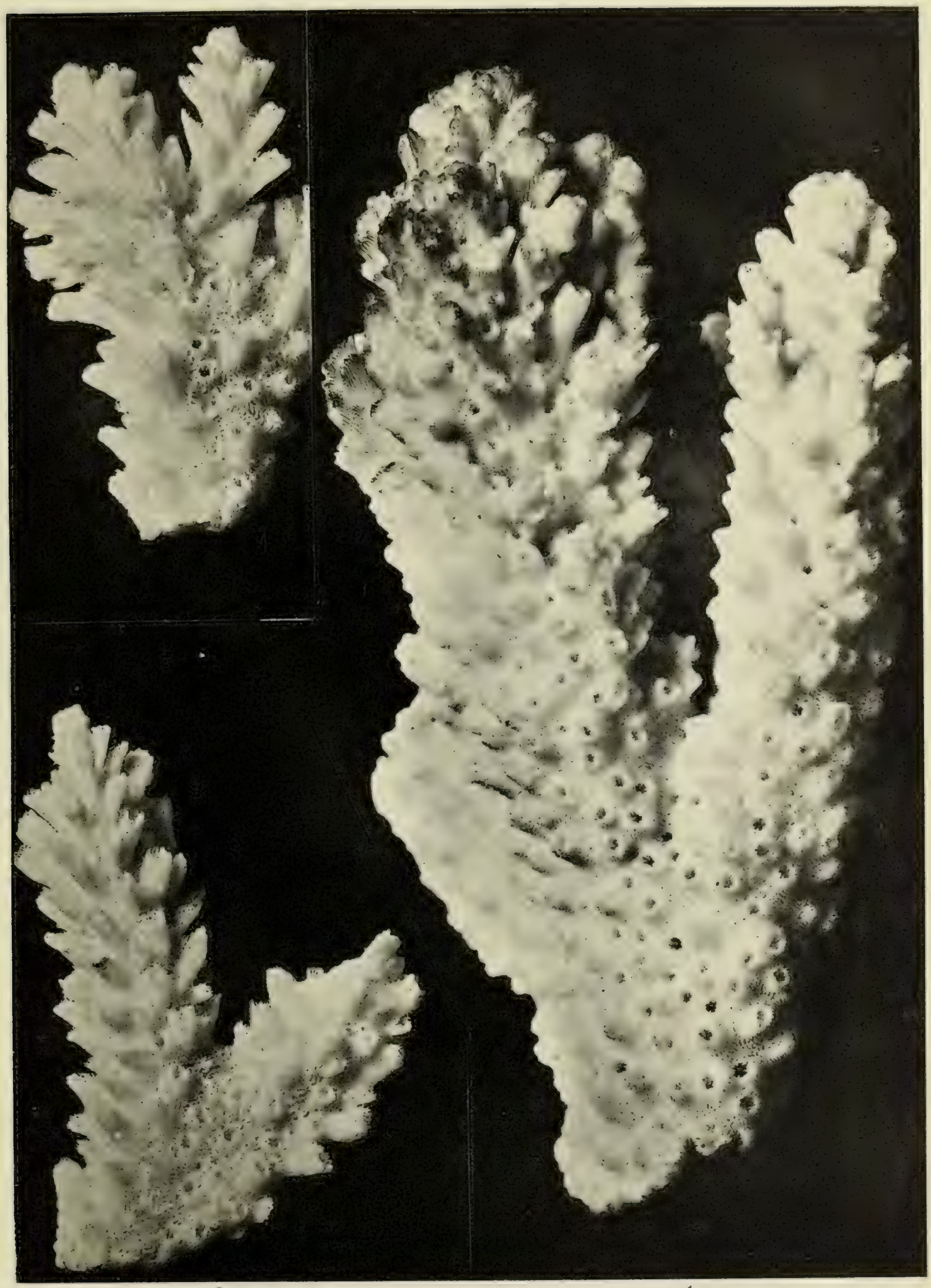
ACROPORA DIOMEDEAE.

HELIOTYPE CO., BOSTON.

PLATE 8.

Fig. 1. Acropora mangarevensis, sp. nov., p. 68. A branch, × 2.
Figs. 2, 3. Acropora diomedeae, sp. nov., p. 69. Two branches, each × 2.

2



3 1

FIG. 1. ACROPORA MAGAREVENSIS.

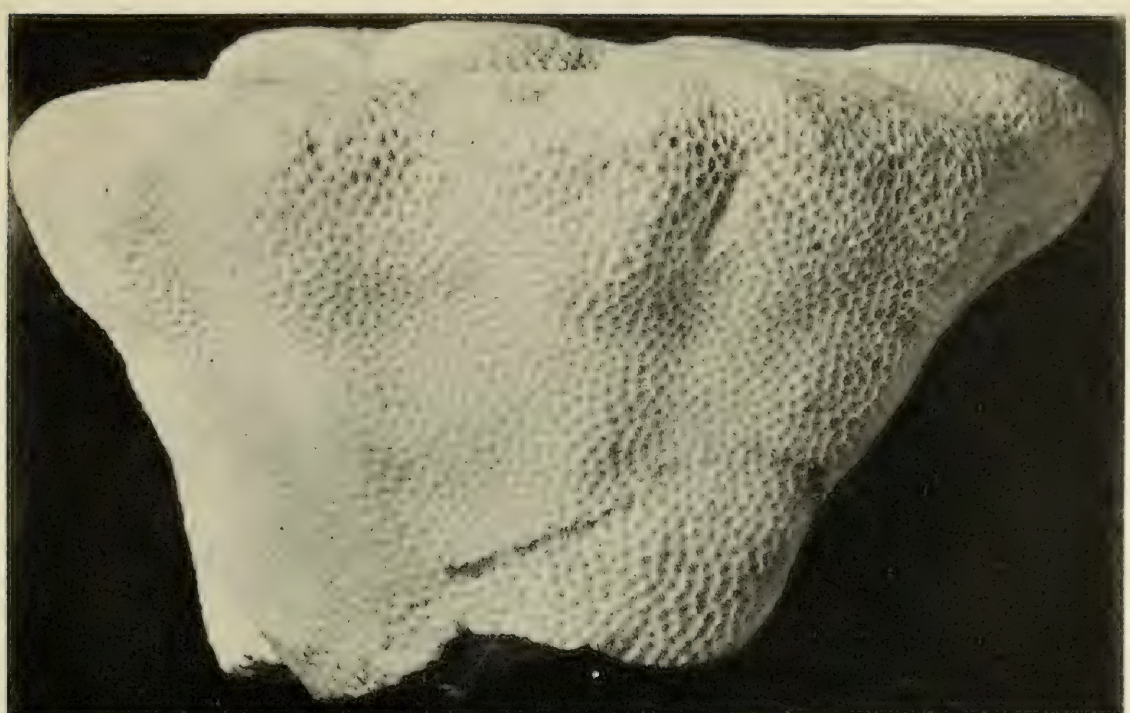
FIGS. 2, 3. ACROPORA DIOMEDEAE.

HELIOTYPE CO., BOSTON.

PLATE 9.

Porites paschalensis, sp. nov., p. 71.

FIG. 1. Upright view of corallum; fig. 2, upper surface, each natural size.



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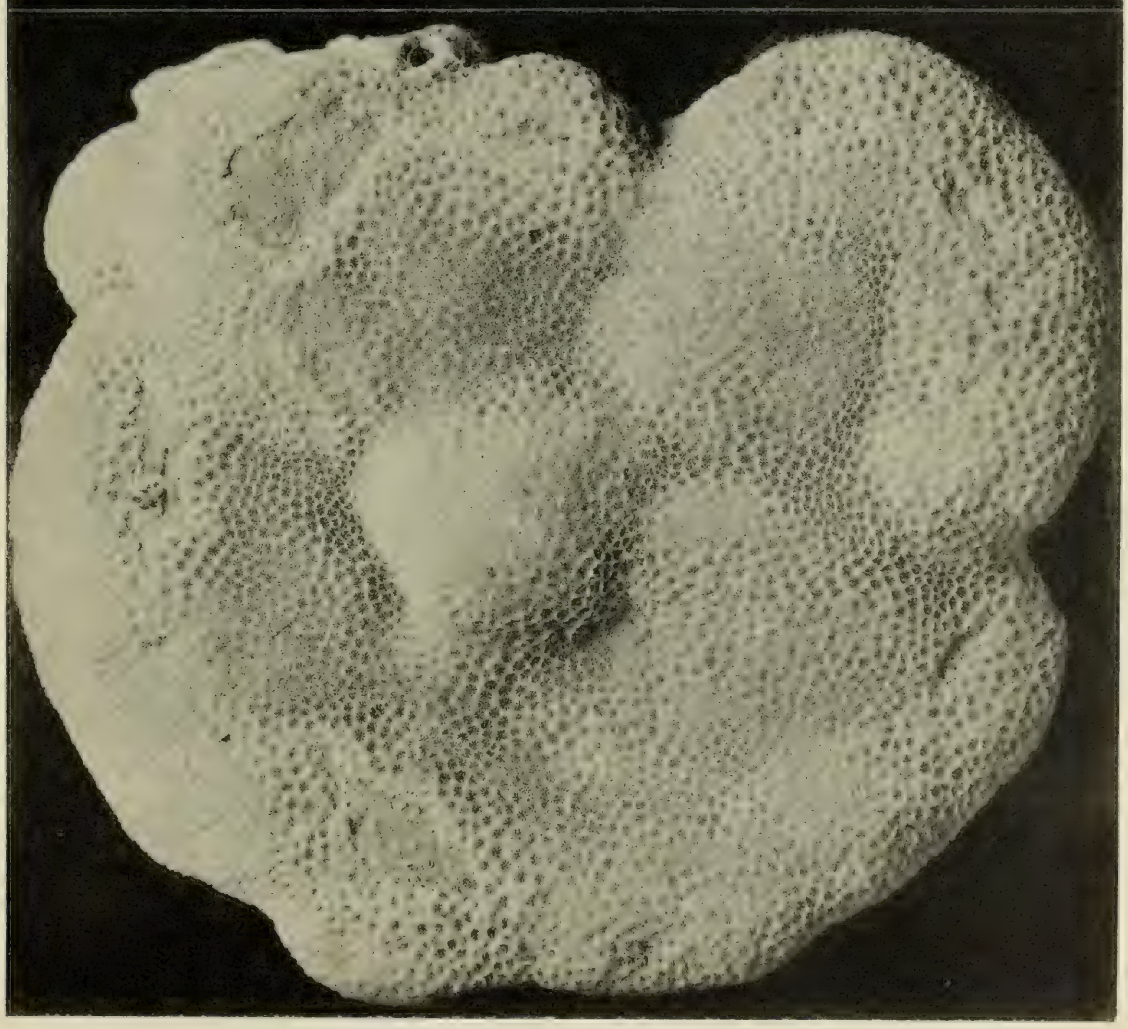


1a

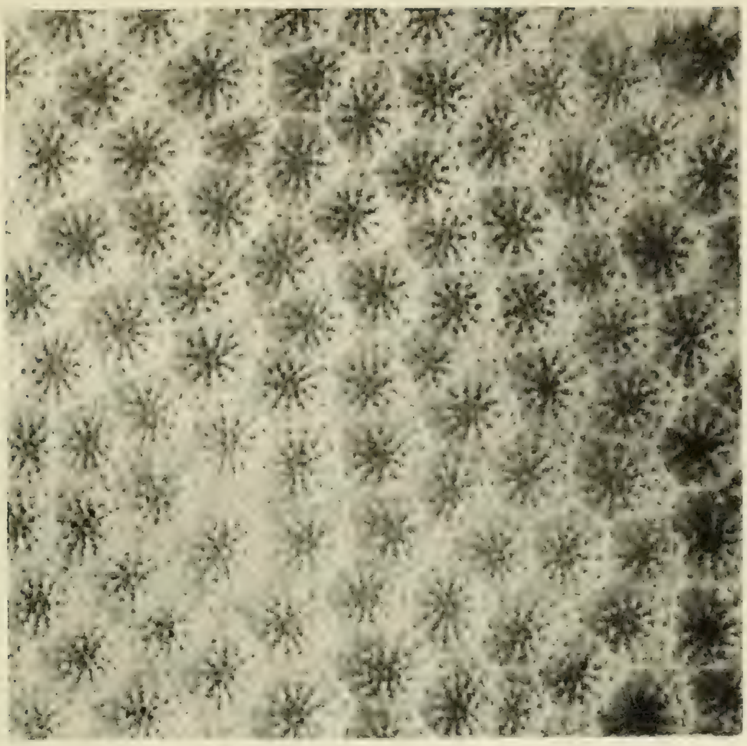
PORITES PASCHALENSIS.

HELIOTYPE CO., BOSTON.

PLATE 10.

Porites paschalensis, sp. nov., p. 71.

FIG. 1. Calices on the side of the corallum; fig. 2, calices of a portion of the upper surface, each enlarged about 6 times.



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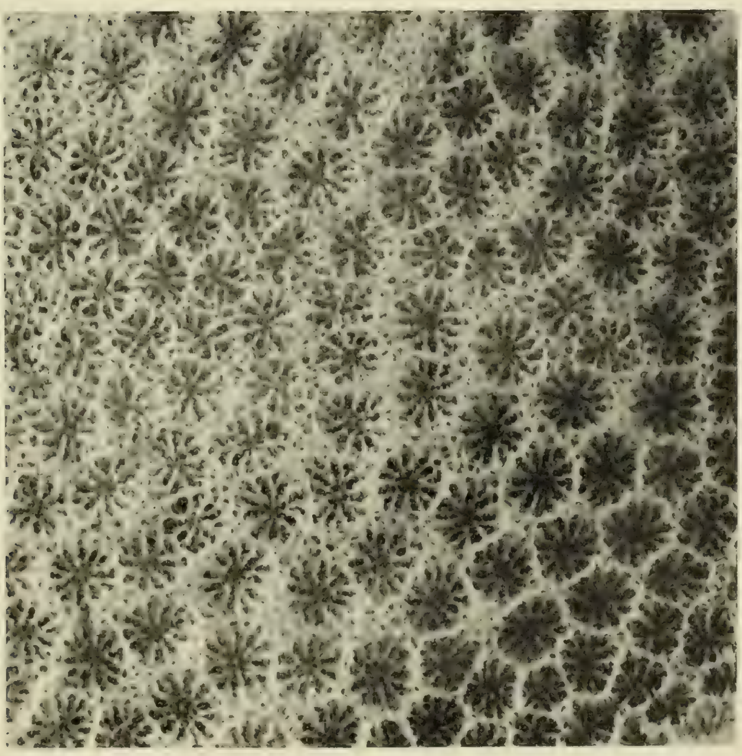

1a

PORITES PASCHALENSIS.

HELIOTYPE CO., BOSTON.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

VOL. L. No. 4.

REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE EASTERN TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM OCTOBER, 1904, TO MARCH, 1905, LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

VII.

SHARKS' TEETH AND CETACEAN BONES.

BY C. R. EASTMAN.

WITH FOUR PLATES.

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No. 4. — *Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross" from October,* 1904, *to March,* 1905, LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

VII.

SHARKS' TEETH AND CETACEAN BONES. BY C. R. EASTMAN.

ONE of the most interesting results of deep-sea dredging in the Pacific is the information that has been gained concerning the distribution of sharks' teeth and Cetacean bones over wide areas of the ocean floor, where, owing to the inappreciable amount of deposition away from the land, it happens that remains of extinct species have lain on the bottom unburied, and are found commingled with those belonging to the modern fauna. Material has now been collected in sufficient abundance, and over sufficiently wide tracts, to acquaint us in the first place with the general facts of distribution, and secondly to furnish data of comparison between fossil and recent forms. A third line of inquiry, which at present can only be suggested, but may possibly be pursued with increasing wealth of material, would be a study of the structural modifications which the auditory organs of Cetaceans have undergone since Tertiary times as the result of adaptation to a purely aquatic habitat.

We may take up first the question of geographical distribution. The most general conclusions that can be drawn from the results of dredging by the "Challenger" Expedition in 1875, and the two "Albatross" Expeditions of recent years (1899–1900 and 1904–1905), are these: —

1. Teeth of Lamnidae and Carchariidae occur in all parts of the Pacific, but are much more plentiful in southern tropical regions than elsewhere.

2. Cetacean ear-bones are found only exceptionally north of the equator, but are abundant south of it, especially between parallels 10° and 40° of south latitude.

3. Amongst Cetacean remains, those belonging to dolphins and Ziphioids are the most common, and most widely distributed; those belonging to whalebone whales (rorquals) are unknown north of parallel 32° of south latitude; and no indication of large sperm whales has been found in any part of the Pacific, not even in those regions now frequented by Physeteridae.

4. On the last "Albatross" Expedition (1904–1905) the largest hauls of sharks' teeth and Cetacean bones were made at stations lying within so-called barren regions, that is to say, areas far removed from the land, beyond the reach of telluric food-supply, and characterized by a most meagre pelagic fauna. The extent of these regions is sometimes such as to constitute veritable deathtraps, comparable to deserts on the land, for marine vertebrates that happen to have strayed therein. Thus, it is a significant fact that 70 per cent of the entire amount of material obtained during the last cruise of the "Albatross" was dredged from within what Mr. Agassiz has termed the barren area.[1]

One may judge of the extensiveness and variety of the evidence upon which the above generalizations repose from the following brief summary of results of the three expeditions contributing to it. The trans-Pacific cruise of the "Challenger" proceeded eastward from Yokohama to the meridian of 155° W, thence due south to Hawaii, to Tahiti, thence southeastward to the meridian of 130° W, and thence about due east to Valparaiso. Over a dozen stations are distributed along this route from which vertebrate remains were obtained in greater or lesser abundance, the percentage of fish, however, greatly predominating over mammalian. With the exception of two fragments, all the Cetacean bones were derived from red clays and Radiolarian oozes; and as stated by Dr. Murray,[2] none such were observed in any of the terrigenous deposits or calcareous oozes.

[1] The barren area of the Eastern Pacific is thus described by Mr. A. Agassiz in his General Report of the Eastern Pacific Expedition (Mem. Mus. Comp. Zoöl. 1906, **33**, p. 11):

The extensive barren area of the Eastern Pacific is situated a considerable distance from land. It is bounded on the north by the curve indicating the position of — h on Pl. 3*c*, and it is out of the track of great oceanic currents. Similar but less extensive barren tracts have been indicated by the trawling of the "Albatross" Tropical Expedition, and by those of the "Challenger" in the Central Pacific, and in the line from the Paumotos to Valparaiso. All these areas are at a distance from land, where no food comes from telluric sources owing to the steep continental slopes of the adjoining continents.

[2] Murray, J., Report on Deep-Sea Deposits. Scient. Results Chall. Exped. 1891, p. 270.

The same author also makes the following statement regarding the sharks' teeth observed during the "Challenger" Expedition:[1]

The distribution of the sharks' teeth in the deposits is similar to that of the bones of Cetaceans, although they were dredged more frequently. They are most abundant in the red clay areas far removed from land, and especially in those of the central South Pacific; they were less frequently taken in the organic oozes of the deep sea, and only in one or two instances in the terrigenous deposits surrounding continental or other land. It seems undoubted that many of the teeth of sharks and the bones of the Ziphioid whales belong to Tertiary and extinct species.

These results are expressed numerically in the subjoined table, in which are recorded the position, depth, and bottom characters of all "Challenger" stations in the Pacific where sharks' teeth and Cetacean bones were obtained. At various other stations not included in this list, on the run from Hawaii to Peru, a few small teeth and otoliths of indeterminable fishes were brought up. Otoliths, on account of their dense structure and different chemical composition, are less readily destructible than other bones of Teleost fishes. Only in three or four instances were any piscine remains, other than otoliths and teeth, observed in all the deposits examined by the "Challenger" naturalists.

LIST OF "CHALLENGER" STATIONS YIELDING VERTEBRATE REMAINS.

Station Number.	Depth, Fathoms.	Position.		Nature of Bottom.	Number of Specimens.	
		Latitude.	Longitude.		Sharks.	Cetacea.
		° ′	° ′			
237	1875	34 37 N.	140 32 E.	Blue mud.	Several.	0
241	2300	35 41 N.	157 42 E.	Red clay.	1	0
244	2900	35 22 N.	169 53 E.	Red clay.	1	0
248	2900	37 41 N.	177 04 W.	Red clay.	1	0
252	2740	37 52 N.	160 17 W.	Red clay.	5	0
256	2950	30 22 N.	154 56 W.	Red clay.	9	0
274	2750	7 25 S.	152 15 W.	Reddish br. Radiolarian ooze.	Numerous.	13
276	2350	13 28 S.	149 30 W.	Red clay.	250	16+
281	2385	22 21 S.	150 17 W.	Red clay.	116	9
285	2375	32 36 S.	137 43 W.	Red clay.	1,500	50+
286	2335	33 29 S.	133 22 W.	Red clay.	350	90+
289	2550	39 41 S.	131 23 W.	Red clay.	1	5
293	2025	39 04 S.	105 05 W.	Brown Globigerina ooze.	2	1
299	2160	33 31 S.	74 43 W.	Blue mud.	0	1
					2,236+	185+

[1] *Loc. cit.*, p 276.

The second expedition to obtain vertebrate remains from deep-sea dredgings in the Pacific was the "Albatross" of 1899–1900. Its initial line from San Francisco to Tahiti converges toward that run by the "Challenger" from Hawaii to the same island; thence the course lay westward to the Fiji Islands, and thence in a general northwesterly direction to Japan. Between California and Tahiti eleven deep-sea dredgings were made by the "Albatross," four of which yielded vertebrate remains. During the remainder of the voyage three deep-sea hauls were made, only one of which (at Station 183, between Cook Islands and Tonga) yielded such remains. The discovery of Cetacean bones by this Expedition at Stations 2, 13, and 17 is interesting, these being the only instances in which this class of remains has been found north of the equator in any ocean.[1] Dolphins, Ziphioids and the pygmy sperm whale (Kogia) were included amongst the number. The nature and amount of material, together with indications of the depth and bottom characters are given for the several stations along this cruise in the following table.[2]

List of "Albatross" Stations Yielding Vertebrate Remains.

Station Number.	Depth, Fathoms.	Position.		Nature of Bottom.	Number of Specimens.	
		Latitude.	Longitude.		Sharks.	Cetacea.
		° ′	° ′			
2	2368	28 23 N.	126 57 W.	Red clay.	153	15
13	2690	9 57 N.	137 47 W.	Red clay.	58	7
17	2463	0 50 N.	137 54 W.	Globiger. ooze.	1	0
173	2440	18 55 S.	146 32 W.	Red clay.	6	0
183	2472	19 04 S.	167 41 W.	Red clay.	1	0
					219	22

[1] This statement should perhaps be qualified so as to exclude recent burials in deposits now forming along the coasts of continents. Bones of the Manatee, for example, were dredged by Pourtales as early as 1868 at depths between 100 and 400 fathoms off the coast of Florida. These bones are externally much corroded, and their substance has been transformed into an amorphous mass of calcite. Mention of them will be found in L. F. de Pourtales's contributions to the Fauna of the Gulf Stream at great depths. Bull Mus. Com. Zoöl., 1869, **1**, p. 123.

[2] Descriptions of this material have been published as follows: *Agassiz, A.*, Preliminary Report and List of Stations, with remarks on the Deep-Sea Deposits by Sir John Murray. Mem. Mus. Comp. Zoöl., 1902, **26**, p. 1–114. *Eastman, C. R.*, Sharks' Teeth and Cetacean Bones frcm the Red Clay of the Tropical Pacific. *Ibid.*, 1903, p. 179–191.

The next and most recent supply of material was furnished by the "Albatross" Expedition of 1904–1905. The general course of this cruise may be compared to the letter W, the base resting upon Manga Reva and Easter Island, and the three upper points touching at Acapulco, the Galapagos and Callao. In addition, a shorter series of zigzags were run between Panama on the north, and Callao on the south. These routes are all indicated on the accompanying chart (Pl. 3), as are also the limits of the extensive barren area described by Mr. Agassiz. It is noteworthy that the stations from which the largest individual hauls were made lie in about the middle of this belt, the greater plentifulness of remains suggesting that creatures here perished in larger numbers than the general average elsewhere, in consequence of the prevailing starvation diet. All of the remains collected by this Expedition showed a lighter encrustation of manganese as compared with those obtained by previous dredgings. Some of the Ziphioid ear-bones presented a remarkably fresh appearance, implying recent burial; amongst sharks' teeth on the other hand, the root, dentine, and all tissues except the enamel were invariably dissolved away. That many of these specimens have remained unburied on the ocean floor since late Tertiary times is rendered probable by the fact of their belonging to extinct species. The following tabulation of results may be compared with those given above for previous Expeditions.

List of "Albatross" Stations (1904–05) Yielding Vertebrate Remains.

Station Number.	Depth, Fathoms.	Position.		Nature of Botton.	Number of Specimens.	
		Latitude S.	Longitude W.		Sharks.	Cetacea.
		° ′	° ′			
4656	2222	6 54.6	83 34.3	Fine gn. M.	10	3
4658	2370	8 29.5	85 35.6	Fine gn. M., Rad. Oz.	15	1
4666	2600	11 55.5	84 20.3	Lt. gray ooze.	0	5+
4676	2714	14 28.9	81 24	Fine dk. br. ooze.	0	4
4685	2205	21 36.2	94 56	Dark brown clay.	73	6
4693	1142	26 30.1	105 45.2	Rocky.	?	?
4695	2020	25 22.4	107 45	Fine lt. br. ooze.	2	0
4701	2265	19 11.5	102 24	Dk. br. choc. clay.	8	2
4709	2035	10 15.2	95 40.8	Lt. gr. Glob. ooze.	1	12+
4711	2240	7 47.5	94 5.5	Lt. gr. Glob. ooze.	2	4+
4721	2084	8 7.5	104 10.5	Lt. br. Glob. ooze.	0	7
4732	2012	16 32.5	119 59	Lt. gy. Glob. ooze.	1	0
4736	2289	19 0.4	125 5.1	Dk. br. choc. mud.	20	4
4740	2422	9 2.1	123 20 1	Dk. gy. Glob. ooze.	1	3
					133	51+

From the foregoing table it will appear that out of a total of thirteen stations from which sharks' teeth and Cetacean bones were obtained, remains of the former to the number of 133 were dredged from ten stations, and of the latter to the number of 51 from eleven stations. Three stations, all lying outside the barren area as defined by Mr. Agassiz (Nos. 4666, 4676, 4721), afforded indications of Cetaceans alone; and two stations, both lying within the barren area (Nos. 4695 and 4732) yielded sharks' teeth without admixture of Cetacean bones. Possibly this last circumstance may be purely fortuitous; or again, on the other hand, it may suggest that whales and dolphins were on the whole less precipitate than sharks in venturing upon a tract of greatly diminished food supply. If this were so, one might expect the gregarious habits of Cetaceans to have had something to do with their avoidance of a barren area. Stragglers might wander in, but the tendency of herds would be to confine their range to areas affording a sufficient food supply.

General Summary of Results by Stations.

Station 4656, depth 2222 fathoms. — There were brought up by the dredge from the bottom at this station 10 sharks' teeth, amongst which 4 are recognizable as belonging to the genus Lamna, 1 to Oxyrhina, 1 to Carcharodon, this last being a fine specimen (Plate **2**, Fig. 21), and the rest merely fragments. The Cetacean material consisted of 1 tympanic bulla of Hyperoodon, 1 periotic of Kogia or some very similar form, and one indeterminate long and slender bone. Most of these remains are but slightly encrusted with manganese.

Station 4658, depth 2370 fathoms. — 4 teeth of Oxyrhina, 9 Lamna, 2 nondescript fragments; also 1 Delphinoid tympanic. Manganese coating very slight.

Station 4666, depth 2600 fathoms. — No fish remains; 4 excellently preserved ear-bones of Hyperoodon, one having the tympanic still fused with the periotic; also 1 heavily encrusted Delphinoid tympanic, and several corroded osseous fragments.

Station 4676, depth 2714 fathoms. — No fish remains; 3 rather heavily encrusted ear-bones of Hyperoodon (Plate **3**, Fig. 36), and 1 unrecognizable fragment.

Station 4685, depth 2205 fathoms. — This station, which lies within the barren area, is remarkable for having furnished a larger number of vertebrate remains than any other during the cruise, and with them were brought up one and one-half tons of manganese nodules. There are in all

73 sharks' teeth, 5 of which belong to Carcharodon, the rest to Lamna and Oxyrhina. Some of the teeth are embedded in nodular masses; none have the crowns heavily encrusted, but the majority have dark brown clay adhering to them. Cetaceans are represented by 5 Delphinoid ear-bones; the tympano-periotic of one individual consists of a single piece.

Station 4693, depth 1142 fathoms. — According to the published record of "Albatross" dredging stations, in the *General Report of the Expedition*,[1] sharks' teeth and Cetacean bones came up in the trawl at this locality. None such are contained, however, in the collection submitted for examination, the only specimen marked with this station number being a well preserved tergum of Lepas.

Station 4695, depth 2020 fathoms. — The vertebrate remains dredged at this point are confined to two small and tolerably fresh-looking Oxyrhina teeth.

Station 4701, depth 2265 fathoms. — 8 sharks' teeth, including 1 large and beautifully preserved Carcharodon, wholly unencrusted, also 1 large and 6 smaller Oxyrhina teeth, very lightly coated; 2 Delphinoid ear-bones, likewise with very little coating.

Station 4709, depth 2035 fathoms. — 2 small fresh-looking Lamna teeth; 2 heavily encrusted ear-bones of Hyperoodon, one indeterminate elongate bone, and several smaller fragments; also 9 lightly coated Delphinoid ear-bones.

Station 4711, depth 2240 fathoms. — Two very slightly encrusted Lamna teeth; 2 Delphinoid ear-bones, one being a large, very heavily encrusted tympanic, the other a moderately coated tympano-periotic; also a number of corroded fragments, all charged with manganese, and betraying only obscure indications of organic origin.

Station 4721, depth 2084 fathoms. — No fish remains; 4 Delphinoid ear-bones, and 3 of Kogia or some very similar form.

Station 4732, depth 2084 fathoms. — No fish remains; 4 Delphinoid tympani, 3 specimens of Kogia, one having the tympanic and periotic fused, all lightly coated with manganese.

Station 4732, depth, 2012 fathoms. One splendidly preserved Carcharodon crown without manganese coating, but with several worm-tubes adhering to it (Plate **2**, Fig. 20); no Cetacean bones. This and the next following station lie within the barren area.

Station 4736, depth 2289 fathoms. 1 small Carcharodon, 6 Oxyrhina, 13 large-sized Lamna teeth, all stained dark brown and very thinly coated with manganese; 3 Delphinoid tympani, and 1 much decayed

[1] Mem. Mus. Comp. Zoöl., 1906, **33**, p. 44.

Cetacean tooth corresponding in size to Hyperoodon, more or less chocolate-colored.

Station 4740, depth 2422 fathoms. — 1 splendidly preserved Carcharodon tooth, shown in Pl. **2**, Fig. 23, from the external face; 1 Kogia, and 2 Delphinoid ear-bones.

SYSTEMATIC ACCOUNT OF THE REMAINS.

Elasmobranchii.

(Plate 2.)

The collection contains one hundred and thirty-three sharks' teeth, all referable to three genera of Lamnidae, Lamna, Oxyrhina, and Carcharodon, named in order of their numerical abundance. None of the teeth are preserved in anything like their entirety. The dentine has been dissolved away, leaving only a thin shell of enamel, and the loss of the root and lateral denticles (in all cases where the latter were formerly present) is a serious hindrance to accurate determination. It has not been possible to recognize heretofore more than two species with certainty, *Oxyrhina crassa* Ag., and *Carcharodon megalodon* Ag., both of which are widely distributed in Tertiary formations, but unknown in the modern fauna. To this number may now be added with some degree of confidence a third species, which we take to be identical with *Carcharodon lanciformis* Gibbes. These teeth are characterized by having very much flattened crowns, broadly triangular in form, with acutely pointed apex and finely serrated lateral margins (Plate **2**, Figs. 19–22). They are readily distinguished from *C. megalodon* by their great lateral compression and usually smaller size. Their separation from the existing *C. rondeletii* is less easy, differential characters being found in the presence or absence of lateral denticles, and the form of the coronal apex. These three species which we are able to recognize with tolerable certainty in deep-sea deposits, namely, *Oxyrhina crassa, Carcharodon megalodon,* and *C. lanciformis,* likewise occur associated with one another in the Phosphate beds of South Carolina and other Tertiary localities.

Illustrations of a selected series of sharks' teeth from the Eastern Tropical Pacific are shown in Plate **2** of this Bulletin. As the features presented by the newly acquired shark material are essentially the same as have already been described at sufficient length in the "Challenger" and "Albatross" Reports, no good purpose would be served by mere repetition of details in the present paper. Contrariwise, the earlier Reports contain only a meagre account of Cetacean ear-bones,[1] hence we

[1] Some of the generic determinations in the previous Reports are clearly open to question. In particular, Kogia and Globicephalus have been confused.

shall do well at this time to devote a larger share of attention to the deep-sea Mammalian remains.

Cetacea.

Cetacean remains were dredged in greater abundance, and from more numerous localities, during the "Albatross" Expedition of 1904–1905 than on the previous cruise of this vessel in the tropical Pacific. The Expedition of 1904–1905 was also successful in bringing up Cetacean teeth for the first time from great depths, two such being contained in the collection. On the other hand, no indications of Mystacocete whales were observed, and it is regarded as quite remarkable that neither the "Albatross" nor "Challenger" Expeditions encountered any traces of the great sperm whale (*Physeter macrocephalus*), notwithstanding that numerous hauls were made within the usual habitat of this animal. Remains of the closely allied pygmy sperm whale, however, occurred at several localities. Ear-bones of Dolphins constitute the greater part of the material, as might be expected, although apparently not more than one or two species are represented. Next in order of abundance are the ear-bones of Hyperoodon, whose habits are gregarious. Several specimens belonging to this genus are scarcely discolored, and present an exceedingly fresh appearance.

The state of preservation of the remains as a whole differs in no respect from that which has been previously observed, and is described by Professor Sir William Turner in following language: [1]

> The preservation of the ear-bones and of the fragments of the beaks of ziphioid whales is accounted for by the extreme density of these portions of the skeleton. Some of the bones were in a much better state of preservation than others. In some the manganese coating was extremely thin, and but little had entered into the Haversian canals and lacunae, so that a fractured surface was greyish-white (Mr. Murray's Pl. X. Figs. 1*a*, 1*b*, 2*a*, 4*a*). Others again were not only thickly encrusted with the mineral, but the Haversian canals and lacunae were infiltrated with it, so that a fractured surface was dark brown or black, and the bones were extremely brittle. The chemical composition of these bones was thus entirely altered, and this was more especially the case with the fragments of the flat bones, and others of a more porous texture which formed the nuclei of so many of the manganese and iron nodules. . . . It is to be noted that the bones obtained did not present any evidence of having been rolled or rubbed. They had evidently rested quietly in the spots where they had been deposited, and in many cases the tympanic and petrous bones were still attached to each other, although they could be separated by the exercise of but little force.

[1] Turner, W., Report on Bones of the Cetacea. Sci. Results Chall. Exped. Zoöl. vol. 1, 1880, p. 41.

This last observation with respect to fusion between the tympanic and periotic applies also to material obtained by the "Albatross" Expedition, and it is interesting to note that some specimens still have the stapes preserved in its natural position. This is the more remarkable in view of the fact that the stapes is not anchylosed, but firmly held in place by muscular attachment within its proper aperture, the *fenestra ovalis*. We will return to a description of the different parts further on.

The question is apposite whether any certain identifications can be made between these deep-sea remains and fossil or recent Cetaceans. In the case of the "Albatross" material it must be acknowledged that no specimens can be positively referred to extant species. The differences they present are all of minor nature, and yet sufficient in the aggregate to make it extremely hazardous to pronounce in favor of absolute identity. One may safely affirm that the bones here referred to Kogia and Hyperoodon differ specifically from *K. breviceps* and *H. rostratus*, but as for undertaking comparisons with other existing representatives of these genera, there is not only great lack of material, but the published descriptions and illustrations are singularly inadequate. Confusion exists as to what species should be properly retained in the former genus, and the second known species of Hyperoodon, *H. planifrons* rests upon the evidence of a solitary water- and pebble-worn skull. On the other hand, a number of well preserved fossil ear-bones of Hyperoodon are available for comparison, which will be referred to later, but none have hitherto been found of the genus Kogia. The range of comparison amongst fossil Delphinoid remains is limited, since most of the extinct forms belong to the Platanistid division, and hence are not properly classed with true Dolphins. The affinities of the deep-sea ear-bones seem to be rather with the Delphinidae proper, and some of them show considerable resemblance with those of the existing *Delphinus delphis* Linné (*cf.* Plate **3**, Figs. 30–32).

The conclusions just stated all have reference to the "Albatross" material. Turning now to that obtained by the "Challenger," we find identifications made with four existing species, whose remains, however, were all dredged from more southerly areas than were visited by the "Albatross." The greater number of "Challenger" ear-bones are believed by Professor Sir William Turner to belong to extinct forms, his remarks on this subject being as follows: [1]

The sharks' teeth belonged to the genera Carcharodon, Oxyrhina, and Lamna, and are to be referred to no species, so far as we know, now living. The question

[1] *Loc. cit.*, p. 42.

therefore naturally arises, Are the cetacean remains associated with them on the floor of the ocean, the bones of existing or extinct forms? Of the resemblance of the greater number of these bones, more especially the tympanic bullae, to existing genera, I have given a number of examples, and have occasionally had to point out how closely some of them correspond with existing species, so that they may be referred to them. But whilst these may be the bones of species still extant, there are others which present greater difficulties in the identification, so that, like the sharks, they may have belonged to animals which had lived in a previous geological epoch.

Neither the authority quoted, nor others who have occupied themselves with the study of Cetacean ear-bones, speak of having undertaken comparisons between deep-sea and fossil material; and although the general anatomy and taxonomic characters of these organs are subjects of great importance, and afford a promising field of inquiry, it cannot be said that they have received the attention they deserve on the part of either palaeontologists or cetologists. Insufficiency of material for comparison is of course largely responsible for this neglect: or if not actually insufficient, it is at least difficult to obtain a first-hand acquaintance with the fossil supply, owing to its scattered distribution in New and Old World museums. Another requisite involving some experience is a nice perception of the degrees of difference or resemblance which fossil and recent material offer on comparison with that dredged from the ocean bottom. It thus appears that the subject is well hedged about with difficulties. It is always advisable, however, to recognize the natural limitations of whatever problem one may be engaged upon, and to refrain from striving after greater accuracy than the nature of the subject permits.

In view of the circumstances just mentioned, we cannot attempt more than a recapitulation of the principal characters of Cetacean ear-bones, and an inquiry into the more general relations between Tertiary species and those brought to light by the "Albatross" dredgings. Before entering upon this discussion it may not be inadvisable to give a brief account of fossil ear-bones, and also to describe a single recent example for the purpose of making our comparative observations more intelligible. This procedure would seem to be necessary to an understanding of various minutiae, the importance of which for systematic purposes has been overlooked. We will consider these different points in order.

Ear-bones of Fossil Cetaceans.

Ear-bones of fossil whales appear to have been first recognized as such by Baron J. von Hüpsch, an amateur collector of Cologne, who described

in 1794 several specimens pertaining to the Balaenidae from the Antwerp Crag, and records having some in his possession from America as well.[1] Thereafter, remains of this sort attracted but little attention on the part of naturalists, not even excepting Cuvier, until the late P. J. Van Beneden began his important researches on recent and fossil Cetacea during the third decade of the last century. Indeed, one of the earliest papers of the Belgian cetologist relates to the identification of rorquals from the Antwerp Crag by means of a comparative study of ear-bones:[2] and another, published the same year, has for its title: "Observations sur les caractères specifiques des grands Cetacés, tirés de la conformation de l'oreille osseuse."[3] During the early forties, fossil ear-bones were discovered in the Red Crag of Suffolk, and on being shown by agricultural chemists to contain a large proportion of lime phosphates, the deposits containing them were actively exploited. Owen refers to the economic importance of the strata, estimating that many thousand pounds annually of the superphosphates were derived from its concretions, and that "thousands of cubic acres of earlier strata must have been broken up to furnish the Cetacean nodules of the 'Red Crag.' This is a striking instance of the profitable results of a seemingly most unpromising discovery in pure science — the determination of what in 1840 was regarded as a rare, unique, and most problematical British fossil."[4]

Although our knowledge of British fossil Cetacea was largely increased by Owen, his attention was only incidentally engaged by ear-bones, and it is to the later investigations of Lankester, Flower, and Lydekker[5] that we owe our chief information in regard to English material. Casual references occur to this class of remains in the writings of American palaeontologists, but no attempt has thus far been made to collect the results of their scattered observations. Indeed, instances are not wanting where these organs have been entirely overlooked, although

[1] Beschreibung einer neu entdeckten versteinerten Theile grosser Seethieren. Der Naturforscher, 3 Stuck, p. 178–183, 1774. The date of publication is also given as 1794 by Van Beneden and Gervais in their work on Cetaceans, one of their species being dedicated to the Baron, "qui a bien connu ces ossements fossiles à la fin du siècle dernier."

[2] Mention du gîte important d'Anvers. Bull. Acad. Roy. Belg., 1835, **2**, p. 67.

[3] Comptes-rendus 1835, **3**, p. 401.

[4] Palaeontology, p. 343, Edinburgh, 1860. Hist. Brit. Foss. Mammals, p. 536.

[5] Complete references are given in Dr. Lydekker's paper on Cetacea of the Suffolk Crag (Quart. Journ. Geol. Soc. (1887), **43**, p. 7–18), and in his Supplement to the Catalogue of Fossil Mammals in the British Museum (1887).

preserved in natural association with the skull, a conspicuous example being the type of *Lophocetus calvertensis* (Harlan). Thus it appears that the subject is eminently worthy of further cultivation, and one is gratified to note that within the last few years signs of renewed interest have become manifest in the writings of several continental palaeontologists, notably Abel,[1] Dal Piaz,[2] and Flot.[3]

Any comparative study of the bones related to the organ of hearing in Cetaceans, whether fossil or recent, must take careful account of certain minutiae, the nature of which may best be explained by describing these parts in a typical example, such as is furnished by the recent *Delphinapterus leucas.* The description here offered will be found to correspond closely with the accounts that have recently been given of the auditory organs of the Porpoise by Beauregard,[4] Denker, and Boenninghaus, whose papers contain a mass of valuable information, both anatomical and physiological, besides abundant references to the literature. We have also adopted the same designations of parts as employed by these authors, and have arranged and lettered the accompanying text figures so as to correspond with the series of *Phocaena communis* given by the last mentioned. The aspects selected for illustration are obtained by rotating the specimen upon its axis through successive quadrants, and then turning it end for end. There are thus shown in order the external, superior, internal, and inferior surfaces, and finally the two end-views.

General Characters of Cetacean Ear-Bones as Illustrated by Delphinapterus.

(Text-figures A–F.)

In the genus under consideration, as in Delphinoids generally with the possible exception of Platanista, the united tympanic and periotic

[1] Abel, O., Untersuchungen über die fossilen Platanistiden des Wiener Beckens. Denkschr. k. Akad. Wissensch. (1900), **68**, p. 839–874. Les dauphins longirostres du Bolderien des environs d'Anvers. Mém. Mus. Roy. d'Hist. Nat. Belg. Année 1901, p. 1–95. Part II., *ibid.*, 1902. Eine Stammtype der Delphiniden aus dem Miocän der Halbinsel Taman. Jahrb. k.k. geol. Reichsanst. (1905), **55**, p. 375. Les Odontocètes du Bolderien d'Anvers. Mém. Mus. Roy. d'Hist. Nat. Belg. Année 1905, p. 1–155.

[2] Dal Piaz, G., Sugli avanzi di Cyrtodelphis sulcatus dell' arenaria di Belluno. Palaeont. Ital. (1903), **9**, p. 187–219. Part II., *ibid.* (1905), **11**, p. 253–280.

[3] Flot, L., Note sur les Cetacés fossiles de l'Aquitaine. Bull. Soc. Géol. France (1896), **24**, p. 270–282.

[4] Beauregard, H., Recherches sur l'appareil auditif chez les mammifères.

has only a ligamentous connection with the surrounding bones of the skull, and hence readily becomes detached from the latter in maceration. The body of the tympanic corresponds to the bulla tympanica of various other Mammalia, that of the periotic, which somewhat resembles the figure 6 in form, to the petrous bone. Processes are developed by each by means of which the two elements are conjoined at either end, leaving a narrow longitudinal slit between them, known as the "tympano-periotic fissure." Although anchylosed in the adult, thus justifying the term of tympano-periotic, the two bones are easily separable in young individuals. During early stages, also, according to Boenninghaus,[1] these bones form almost an integral part of the periotic region of the cranium, and are oriented with their long axis parallel with the median line of the body, the spout-like aperture for the Eustachian canal being placed foremost. The elements soon become protruded downward, however, and a recess is formed for them on the side of the base of the cranium; owing to the more rapid increase in width of the hinder portion of the skull, the main axis of the tympano-periotic becomes shifted so as to be directed almost diagonally with reference to the longitudinal axis of the body. Notwithstanding this obliquity of position, it is customary to speak of the two extremities as anterior and posterior respectively, and of the lateral walls or "lips" of the bulla as external and internal. The latter bone is hollow, broad, rounded, and distinctly bilobed behind, pointed in front, and open above except for a short distance posteriorly where the process for attachment with the periotic forms an archway spanning over both lips. Immediately in front of this process is a somewhat crescentic opening for the external auditory meatus, closed in the living animal by the membrana tympani.

The periotic is an irregular bone, somewhat shorter than the tympanic; its central rounded portion or promontory, which encloses the cochlea, is very dense, and pierced by several openings. On the cerebral side is seen the large *meatus auditorius internus*; on the surface opposed to the tympanic cavity the *fenestra ovalis* (or *vestibuli*), which receives the stapes, and directly above it the aperture for the Fallopian canal; nearly in line with them below, and looking posteriorly, is the somewhat larger *fenestra rotunda*, otherwise known as the *fenestra*

Journ. Anat. Physiol. (1894), **30**, p. 366–413. Denker, A., Zur Anatomie des Gehörorgans der Cetacea. Anat. Hefte (1902), **19**, p. 423–448. Boenninghaus, G., Das Ohr des Zahnwales. Zool. Jahrb. Anat. (1904), **19**, p. 189–360.

[1] *Loc. cit.*, p. 225.

cochleae. We will now describe the different aspects of the subject selected for illustration, beginning with the external.

External face (Fig. A). — The most obvious feature of the outer lip (1) of the bulla ossea relates to the presence of certain processes along the superior margin. There is one at either extremity, termed respectively the *processus anterior* (3) and *proc. posterior* (4), whose function is to unite the tympanic and petrous (2) bodies in the manner already explained. These are the only points of contact where the two bodies are actually fused, and they are completely separated below by the

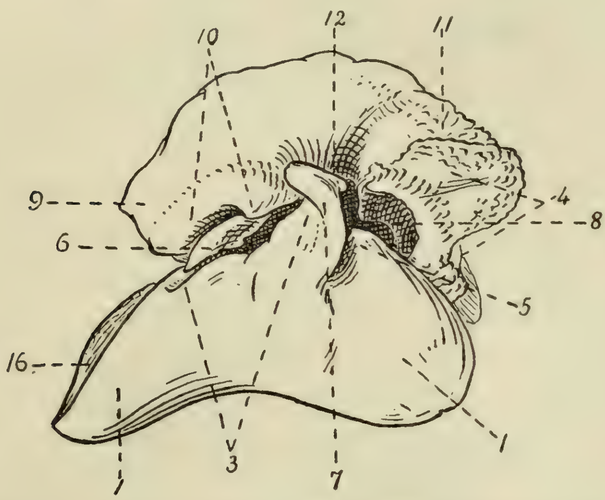

FIG. *A*. — Left tympano-periotic of the existing *Delphinapterus leucas* Pallas. External face, × $\frac{1}{1}$.

The same numbers are used in Figs. A–F for the following parts: 1, Bulla tympanica (outer lip); 2, Petrosal; 3, Proc. ant. bullae; 4, Proc. post. bullae; 5, Proc. conicus bullae (= rudimentary inferior wall for external auditory meatus); 6, Proc. tubarius (= part of anterior process supporting so-called "accessory ossicle"); 7, Proc. sigmoideus (= rudimentary anterior wall of external auditory meatus); 8, Position of membrana tympani; 9, pointed anterior extremity of petrous body; 10, Proc. ant. petrosi; 11, Proc. post. (mastoideus) petrosi; 12, Hiatus epitympanicus; 13, Aptertura extern. aquaeductus vestibuli; 14, Apertura extern. aquaeductus cochleae; 15, Porus acusticus internus; 16, bulla tympanica (inner lip); 17, Fissura tympano-periotica; 18, Orificium (Hiatus) tympanicum; 19, Apertura tympanica canalis Eustachii; 20, Groove for the nervus facialis; 21, Fenestra cochleae.

tympano-periotic fissure (17). There are developed in the intermediate space between these processes two others, the more prominent of which is singularly formed, and receives the name of *proc. sigmoideus* (7). The smaller one closely adjoining it is of conical form, and provides a corresponding recess within the tympanic cavity immediately below the *porus acusticus*, or aperture in which the tympanic membrane is suspended. It is numbered 5 in figures A and E, and may be referred to

for short as the *processus conicus.* Beauregard terms it "apophyse conique postèrieure," Boenninghaus "processus medius." The conformation of the various parts just indicated is worthy of particular note since they furnish important diagnostic characters.

The anterior process is constricted off from the superior margin of the outer lip by a well-marked groove so as to form a slender tenon-like projection (6), which extends backward as far as the middle portion of the periotic. It is, indeed, partially concealed by the latter bone, with which it fuses after first becoming enlarged into a bulbous or knob-like "accessory ossicle," as it is called by Lydekker. This enlarged portion fits snugly into a corresponding cavity of the periotic, and is usually broken away with that bone, instead of with the tympanic, when the two are forcibly separated. Frequently it is lost in the process of fossilization or maceration, when its appropriate cavity is plainly visible in the periotic. It is to the tympanic, however, that the ossicle properly belongs; and since, according to Boenninghaus, its function is to support the Eustachian canal, it may be compared with the *processus tubarius tympanici* of the horse and sheep.

The posterior process (4) is confluent below with both lips of the bulla, is constricted in the middle, and has an enlarged and elongate upper portion or "head." This upper portion exhibits on the cerebral face a broad articular facette for union with a corresponding process of the periotic, and serves externally for the attachment of cartilage or connective tissue, by means of which the combined tympano-periotic is firmly held in place on the under side of the skull. The posterior process has a more open or fibrous structure than other parts of the element to which it belongs. This condition is not only visible externally, but is very conspicuously shown by the articular facette just mentioned. The coarse striation of this surface contrasts strongly with the smooth appearance of the corresponding parts in toothed whales, and is occasioned by a fan-shaped arrangement of bundles of osseous tissue. Spanning across both lips of the bulla near its hinder extremity, the posterior process extends forward so as to come very nearly, but not quite in contact with the processus sigmoideus. The three processes we have named, posterior, conicus and sigmoideus, enclose between them the rounded aperture across which is suspended the *membrana tympani* (8). The walls which they together take part in forming are interpreted by Boenninghaus as a rudimentary osseous external auditory meatus.

Superior face (Fig. B). — The more conspicuous body appearing from

this aspect is identifiable with the petrous bone of other mammals, and has the usual pointed anterior extremity (9). Immediately behind this is seen a tumid shelf-like projection which overhangs and partly conceals the anterior process of the bulla, together with its "accessory ossicle," being in fact slightly fused with the latter underneath. This projecting portion of the front margin is called the *processus anterior petrosi* (10); and underneath it passes in a longitudinal direction the tensor muscle of the tympanic. The hinder portion of the petrous body forms the posterior process (11), by which, as we have seen, the periotic and tympanic are principally held together. A portion at least of this structure is evidently equivalent to the *processus mastoideus petrosi* of other Mammals. About midway between the two processes referred to, a sinus occurs in the supero-external margin of the periotic which

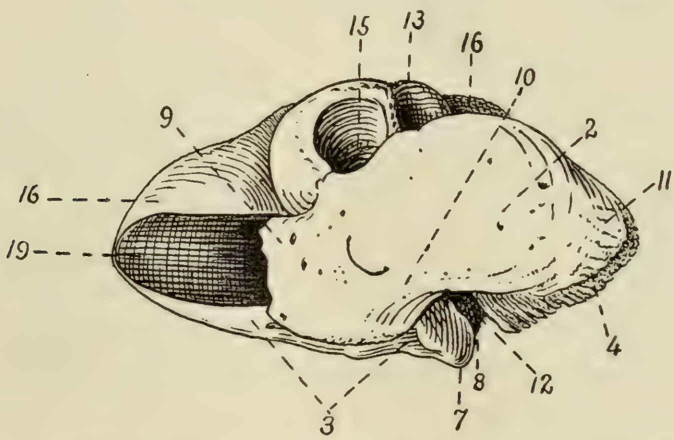

Fig. *B.* — Left tympano-periotic of the existing *Delphinapterus leucas* Pallas. Superior face, × ½.

affords ingress by means of an obliquely descending semicircular conduit (12) into the tympanic cavity. This passageway is named by Beauregard *ductus petro-tympanicus;* by Boenninghaus, who regards it as peculiar to Cetacea, it is called *hiatus epitympanicus.*

Cerebral or inner face (Fig. C). — Viewed from this position, the narrow inner lip (16) of the bulla appears uppermost in the figure (in reality it is lowermost), and immediately below this, yet separated from it by the continuous tympano-periotic fissure, is the rounded portion of the periotic which contains the cochlea. The windings of the scala may be readily followed, the outer wall being formed by the promontory, and the inner spirals appearing within the large funnel-shaped pit known as the *porus acusticus internus* (15), which gives passage for the acustico-facial nerve. In the present form, as indeed in most Delphinoids, the aperture

for the *nervus facialis* is confluent with the *porus acusticus* on that side of the periotic which is turned away from the tympanic, but it sometimes happens, as in Mesoplodon, that these openings are separated. The *nervus facialis* emerges on that side of the periotic which is turned toward the tympanic through a small round aperture (*apertura tympanica canalis Fallopiae*) which is continued backward in the form of a semi-enclosed canal (20). Two other openings are visible on the cerebral face of the periotic, placed one above the other in close proximity to the *porus acusticus*. The smaller of these communicates directly with the cochlear labyrinth, and is only separated from the external opening of the latter (*fenestra cochleae*) by a slight bridge. The name given to this smaller opening is *apertura externa aquaeductus cochleae* (14). The larger one above it is called from its communication with the scala vestibuli the *apertura externa aquaeductus vestibuli* (13). All of these openings vary more or less in form, size, and position amongst different genera, and hence require attentive examination.

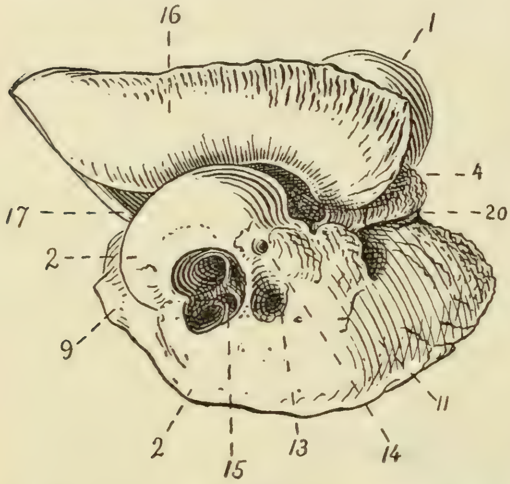

Fig. *C.* — Left tympano-periotic of the existing *Delphinapterus leucas* Pallas. Inner or cerebral face, inverted, × ½.

Inferior face (Fig. D). —Rotation through another quadrant of arc brings into view the lower surface of the bulla ossea. It is traversed longitudinally along its middle portion by a broad sulcus that gradually deepens posteriorly, thus forming an inner (16) and an outer (1) lip. The surface of the latter is smooth, that of the former very rough, the rugosity extending about half-way

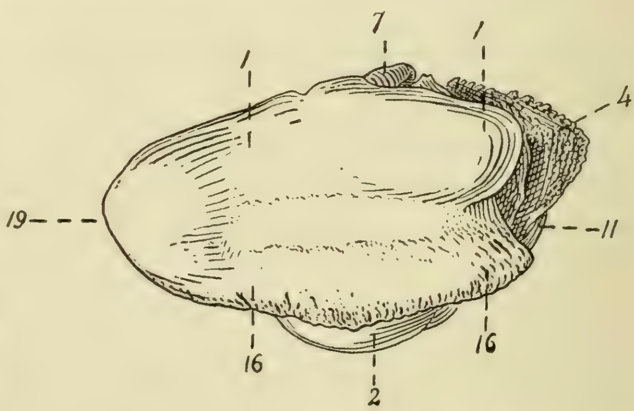

Fig. *D.* — Left tympano-periotic of the existing *Delphinapterus leucas* Pallas. Inferior face, × ½.

up the reflected inner wall of the bulla. The walls are thickest where the surface is rough, and thinnest over the smooth outer lip.

Posterior end (Fig. E). — Viewed from behind, the most marked features are the bilobed form of the bulla, the large size and spongy texture of the posterior processes (4, 11) of the tympanic and periotic, the continuity of the narrow tympano-periotic fissure (17), the large canal for the egress of the facial nerve already referred to (20), and the large opening in the posterior wall of the promontory known as the *fenestra cochleae* (21).

Anterior end (Fig. F). — Above is seen the obtuse forward extremity of the periotic, below the produced and spout-like termination of the Eustachian canal (19). The opening of the latter is not completely en-

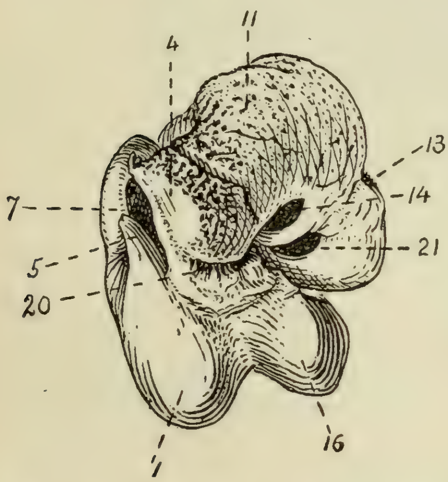

FIG. *E*. — Left tympano-periotic of *Delphinapterus leucas* Pallas. Posterior end, × 1/1.

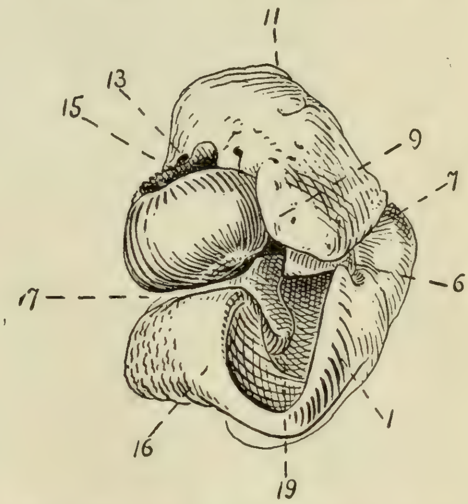

FIG. *F*. — Left tympano-periotic of *Delphinapterus leucas* Pallas. Anterior end, × 1/1.

closed, as in other Mammals, but drawn out into a long slit-like canal, which is confluent above the superior margin of the inner lip with the fissura tympano-periotica (17). A portion of the knob-like "accessory ossicle" (6) of the tympanic is plainly visible below the overhanging anterior process of the periotic (10).

Having now examined different aspects of the periphery, our next procedure would be to separate the two elements of the tympano-periotic, and observe those surfaces which are presented towards each other, and hence remain concealed when the bones are in natural apposition. These inner faces, however, are precisely the ones which have been oftenest figured and described in the case of fossil forms, and as regards the recent Delphinapterus, the general resemblance to Phocaena is such that the

same description will apply to both. We may therefore content ourselves with reproducing one of Denker's illustrations of the latter genus (Fig. G), and referring to his descriptions, as well as those by Beauregard and Boenninghaus, of its auditory organs. The modifications certain

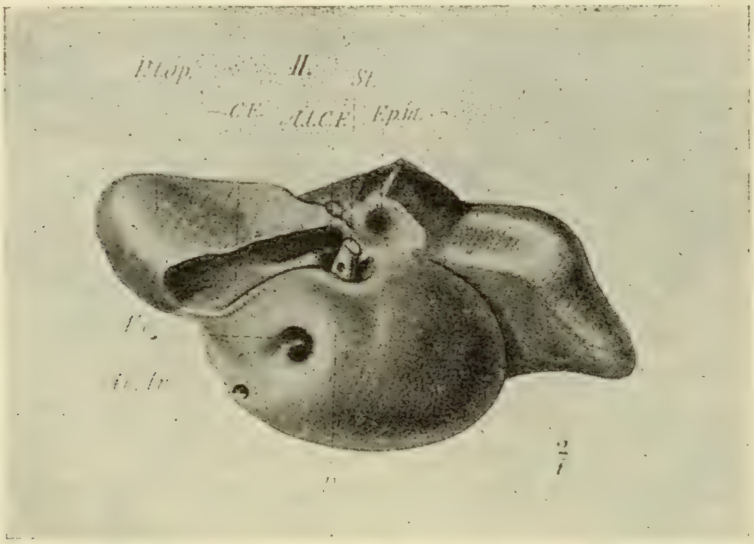

Fig. *G.* — Tympanic aspect of right periotic of *Phocaena communis* Linn. × ¼ (after Denker). *A. t. C. F.*, Apertura tympanica canalis Fallopiae; *A. e. A. c.*, Apertura externa aquaeductus cochleae; *C. F.*, Semi-enclosed canal for the nervus facialis, with groove for the musc. stapedius; *F. c.*, Fenestra cochleae; *F. p. m.*, Pit for head of the hammer; *P.*, Promontory, or capsule containing the semicircular canals; *P. t. o. p.*, Processus tympanicus ossis petrosi; *St.*, Stapes, immovably seated in the fenestra ovalis, but not anchylosed with it by bony union.

parts have undergone for the better perception of sound waves transmitted through the walls of the skull are clearly pointed out by these authors.

Distinctive Characters of Cetacean Ear-Bones.

A brief recapitulation of the more general characteristics of Cetacean ear-bones is here given, by way of directing attention to those features which are available for the distinction of groups of greater or lesser rank. How important these characters really are seems to have been first appreciated by Van Beneden, who remarked in 1885: " Qui aurait pu se douter que la caisse tympanique et la surface articulaire de la mandibule des Mystacocètes auraient pu fournir les caractères les plus importants pour distinguer des genres et même les espèces?" [1]

[1] Ann. Mus. Roy. d'Hist. Nat. Belg. (1885), **9**, p. 2. Emphasis is here laid upon the tympanic, because this is the more characteristic bone amongst the Balaenidae,

MYSTACOCETI.

Balaenidae.

A. Balaenine Section. — The tympanic is deep and more or less rhombic, its inflation comparatively slight, the involucrum (*i. e.*, the reflected superior portion of the inner wall of the bone) not fig-shaped, and frequently with no well marked depression at the anterior extremity of the superior border of the inner surface for the Eustachian canal.

B. Balaenopterine Section. — The tympanic is long, much inflated, rounded, with the involucrum much thickened and more distinctly pyriform, and the notch for the Eustachian canal always well marked. The tympanic varies in different individuals of the same species much less than in the Balaenine section.

ODONTOCETI.

Physeteridae.

The anterior facette of the periotic for articulation with the tympanic is quite smooth; the posterior tympanic surface of the former is broad, and carries a median longitudinal ridge. Tympano-periotic rigidly united with the cranium by a bony process.

Hyperoodon.

The posterior portion of the periotic is shortened, the median ridge on the tympanic aspect of the same very strongly developed, the accessory ossicle (*processus tubarius*) large and rounded, and the anterior tympanic facette slightly concave.

Kogia.

Tympanic and periotic firmly united with each other by their anterior processes only, the posterior processes being widely separated and embracing between them a portion of the mastoid bone. Tympanic bulla scarcely inflated, aperture for Eustachian canal vertically constricted, sigmoidal process knob-like and prominent. The apertures seen on the inner aspect of the periotic (that which is turned away from the tym-

of which the author is speaking, and the one most commonly occurring in the fossil state. Amongst Odontocete whales and Delphinoids, on the other hand, the more important distinctive characters are furnished by the periotic. The analysis here given for the family divisions is taken chiefly from Dr. R. Lydekker's Catalogue of the Fossil Mammalia in the British Museum (1887).

panic) are round, relatively small, and distinct, characters which readily distinguish this element from Delphinoid periotics.

Delphinidae.

The anterior facette of the periotic for articulation with the tympanic is deeply grooved, the posterior tympanic surface of the former is comparatively narrow, and its ridge for articulation with the free border of the tympanic is ill-defined and situated close to one edge. The attachment of the two elements to the cranium is secured by ligaments only, not by bony union. Porus acusticus relatively large and of oval outline.

Delphinus.

Although the ear-bones of the type species, *D. delphis* Linné present easily recognized peculiarities, yet, owing to the restricted sense in which the generic term is now employed,[1] it does not appear possible to formulate a diagnosis from such minor details which will enable us to distinguish this genus from all other Dolphins by means of ear-bones alone. It is to be noted that some of the "Albatross" ear-bones agree very closely with the existing *D. delphis*, the resemblance being closer than with any known fossil species; yet we cannot be sure of absolute specific identity.

Comparisons with recent forms. — The remark just made with reference to Delphinus applies also to Kogia, a genus which has not been recognized with certainty in the fossil state, and is represented by at least three well-characterized living species. The few deep-sea ear-bones which have been obtained do not differ in any material degree from those of the supposed nearest ally of Physeter, *Kogia breviceps.* Three examples are shown in Plate **3**, Figs. 24–26, and one very perfect specimen has been figured in an earlier Report. These may all be assumed to belong either to the pygmy sperm whale or to a closely allied species.

The case of Hyperoodon is somewhat different, inasmuch as the deep-sea ear-bones referred to this genus cannot be identified either with the existing *H. rostratus* or with any known fossil form. Although it is clear that a distinct species is represented, no necessity appears for designating it by a new name, for the simple reason that no satisfactory diagnosis can be framed upon the evidence of ear-bones alone. The principal differences to be noted between the "Albatross" material

[1] True, F. W., Review of the Family Delphinidae. Bull. 36, U. S. Nat. Mus., (1889), 191 pp., pl. 46. — On Species of South American Delphinidae described by Dr. R. A Philippi in 1893 and 1896. Proc. Biol. Soc. Wash. (1903), **16**, p. 133–144.

and the existing *H. rostratus* are as follows: The posterior articular facette of the periotic is more deeply concave in the deep-sea specimens, the "accessory ossicle" (*proc. tubarius*) is relatively smaller and scarcely inflated, the channel for the Fallopian canal on the tympanic aspect is less distinctly marked, and the promontory, or capsule containing the semicircular canals, is less expanded. Some minor differences are also to be observed in the relative size, arrangement, and direction of the apertures seen on the cerebral side of the periotic. The involucrum of the tympanic is not serrated, although the corresponding part in the living species displays as many as six or seven prominent denticles. Two specimens each of the periotic and tympanic, dredged from three different stations, are represented in Plate 2, Figs. 33–36.

Peculiar markings of certain deep-sea ear-bones. It deserves mention, in conclusion, that none of the ear-bones dredged by either of the "Albatross" Expeditions show any indications of surface markings comparable to those observed in two specimens, belonging respectively to the right and left sides, of Balaenine tympanic bullae brought up from one of the "Challenger" stations (No. 286) in the South Pacific. As the bullae are of corresponding form and proportions, and are stated to exhibit similar markings, it is extremely probable that they belonged to a single individual, and that their incised lines are a natural feature, rather than the result of post-mortem injuries. A certain amount of regularity is to be observed in the disposition of the grooves. They are not distributed at haphazard, nor do they intersect one another at varying angles, as we should expect them to were they of accidental origin. Furthermore, the bone substance is so exceedingly hard and dense that a knife-blade makes no impression upon it; only with the file is an incision possible. Yet it has been suggested that the indentations noticed in the "Challenger" ear-bones were caused by sharks' teeth. This conjecture was first advanced by J. Thoulet,[1] and an attempt to lend some color of probability to it was made later by A. Portis.[2]

The authors of the volume on Deep Sea Deposits of the "Challenger"

[1] Thoulet, J., Les depots sous-marins. Rev. Scient., (1892), **50**, p. 105.

[2] Portis, A., Un Dioplodonte nel pliocene astigiano. Rev. Ital. di Paleont., (1897), **3**, p. 34–39. Consult also the earlier memoir of the same author entitled "Nuovi studi' sulle traccie attribuite all' uomo pliocenico." Mem. R. Acc. Sci. Torino, ser. 2 (1884), **35**, p. 327–354. In Plate 1. Fig. 1 of this memoir is shown a tooth of *Carcharodon angustidens* actually embedded in a vertebra of Halitherium,

Reports do not undertake to account for the incised condition of the pair of ear-bones from Station 286, and show the grooved aspect of only one of them in Plate 7, Fig. 5, of their Report. In the explanatory legends, however, it is stated that "the markings shown in Fig. 5 were found on both of the bones, and are of the same character; these are the only bones taken during the cruise with such marks, and they differ from all the other ear-bones in other respects as well as in the markings." Professor Thoulet's interpretation is expressed in such positive terms, and is accepted with such readiness by Dr. Portis, that his views may best be set forth in his own words, as follows:

Une figure de MM. Murray et Renard représente un os de baleine sur lequel sont indiquées des marques arrondies, se coupant mutuellement et ressemblant a s'y méprendre aux incisions couvrant une omoplate de Balaenotus tertiare trouvée à Monte-Aperto, en Italie, par M. Capellini. M. de Quatrefages s'était justement basé sur ces dernières pour admettre l'existence de l'homme tertiare, car il se déclarait dans l'impossibilité de les attribuer à une autre cause qu' à l'action d'un instrument tranchant. L'échantillon du *Challenger*, autant qu'il est permis d'en juger sur des dessins, paraît résoudre la question de la manière la plus nette et contrairement aux conclusions de M. de Quatrefages; les incisions ne peuvent être que la trace des dents de Squales.

The above explanation would undoubtedly answer for any other portion of the skeleton except dental tissue and bones of the auditory region. Its inapplicability to the latter may be demonstrated by a simple experiment. One may take any kind of shark's tooth whatsoever, recent or fossil, and try to obtain similar channelings and indentations on Cetacean ear-bones by forcible rubbing of the parts together. It will be found that the surface of the ear-bone is barely scratched by the apex of the enameled crown; and that, as between the two bodies, the shark's tooth is the more easily worn away.

thus confirming a conjecture made fifteen years earlier by Delfortrie. The latter's publications are to be found in the Actes de la Société Linnéenne de Bordeaux, (1869–72), **27**, **28**.

EXPLANATION OF PLATES.

PLATE 1.

Chart showing position of the stations occupied by the "Albatross" during her cruise in the Eastern Pacific in 1904–1905.

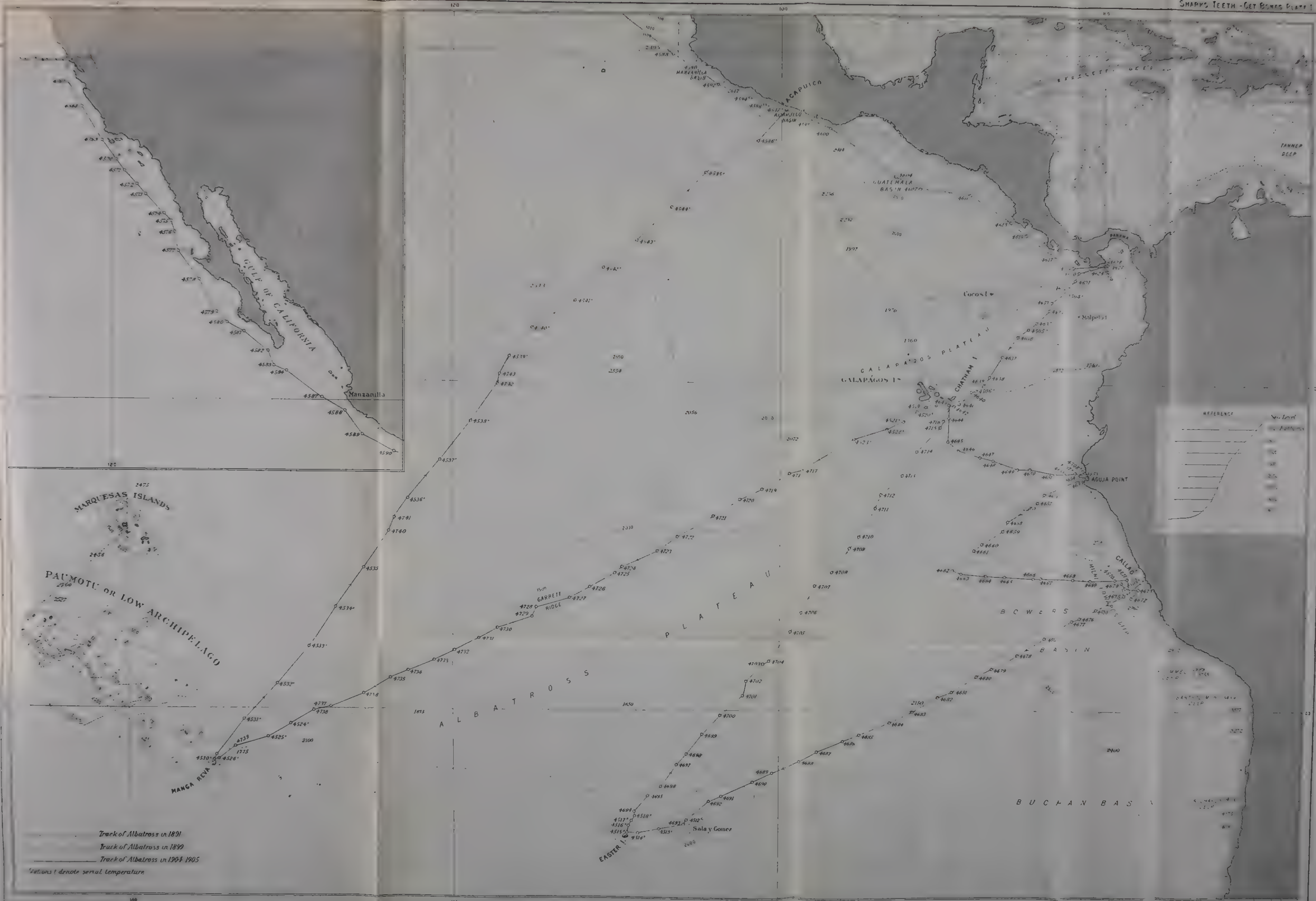
MARQUESAS ISLANDS
PAUMOTU OR LOW ARCHIPELAGO
MANGA REVA
GULF OF CALIFORNIA
Manzanillo
ACAPULCO
GUATEMALA BASIN
GALAPAGOS PLATEAU
GALAPAGOS IS
CHATHAM I
Cocos I
Malpelo I
AGUJA POINT
CALLAO
BOWERS BASIN
BUCHAN BAS
ALBATROSS PLATEAU
GARRETT RIDGE
EASTER I.
Sala y Gomez
Track of Albatross in 1891
Track of Albatross in 1899
Track of Albatross in 1904-1905

PLATE 1a.

Chart showing tracts of the " Albatross " and " Challenger " Expeditions in the Pacific. Stations yielding vertebrate remains indicated by round dots ; the so-called barren region by oblique lines.


Stations :
"Challenger"
"Albatross"
"Albatross"
"Albatross"
"Albatross"
Barren Area
"Challenger"

PLATE 2.

(*All figures are of the natural size.*)

Figs. 1–3. *Oxyrhina crassa* Ag., Station 4658. Small postero-lateral teeth seen from the inner or convex face.

Figs. 4, 5. *Oxyrhina crassa* Ag., Station 4656. Small postero-lateral teeth.

Figs. 6, 7. *Lamna* sp. ind., Station 4656. Two anterior teeth of a small species seen from the inner or posterior aspect.

Figs. 8, 9. *Oxyrhina crassa* Ag., Station 4701. Small postero-lateral teeth.

Figs. 10–12. *Oxyrhina crassa* Ag., Station 4685. One anterior and two lateral teeth, all seen from the inner, convex face.

Fig. 13. *Carcharodon lanciformis* Gibbes, Station 4685. Small posterior tooth having manganese concretions attached to it.

Figs. 14–16. *Oxyrhina crassa* Ag., Station 4685. Anterior teeth, seen from different faces, and having small nodular masses of manganese attached to them.

Fig. 17. *Oxyrhina crassa* Ag., Station 4685. Small posterior tooth having the interior filled with concretionary manganese.

Fig. 18. *Oxyrhina* sp. ind., Station 4701. Finely preserved tooth of less robust form than the preceding, not unlike *O. hastalis* in some respects, and with scarcely any incrustation.

Figs. 19–22. *Carcharodon lanciformis* Gibbes, from following stations in consecutive order: 4685, 4732, 4656, and 4685. All seen from the inner face, which is but slightly convex. The original of Fig. 20 has several worm tubes attached to it.

Fig. 23. *Carcharodon megalodon* Ag., Station 4740. Very large and well preserved lateral tooth, seen from flattened external face. The interior is filled with a deposit of manganese.

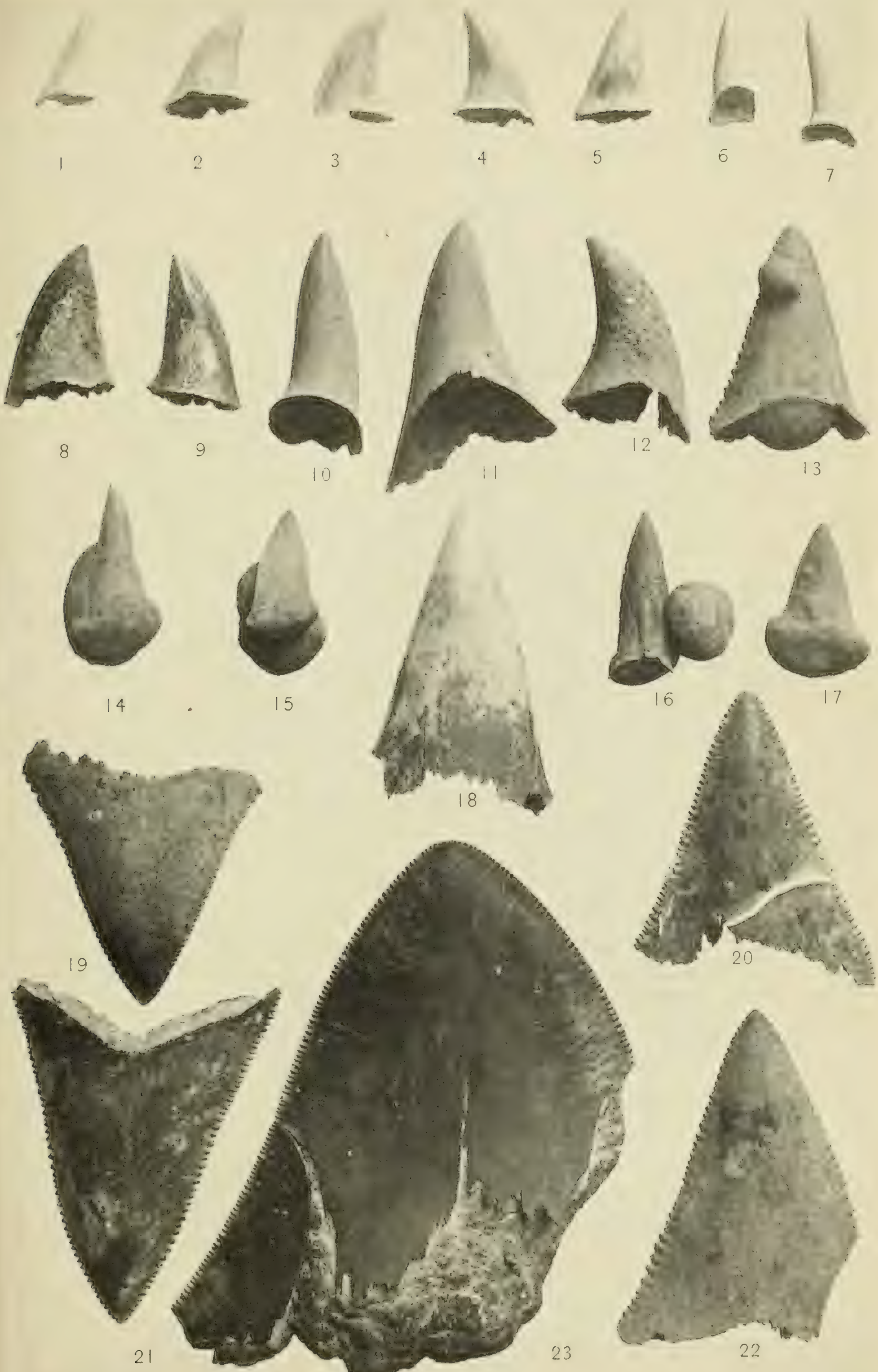

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PLATE 3.

(*All figures are of the natural size.*)

Figs. 24, 25. *Kogia* sp., very similar to *K. breviceps.* Left and right periotics, respectively, the former from Station 4740, the latter from Station 4721.

Fig. 26. Imperfect right tympanic belonging to same species as the preceding, from Station 4721.

Figs. 27, 28. *Delphinus* sp., somewhat resembling *D. delphis.* Left and right periotics respectively, from Stations 4701 and 4740. The right periotic is seen from the tympanic aspect, and has the stapes still seated in the fenestra ovalis. The longitudinal extent of the porus acusticus, as compared with that in Fig. 25, is noteworthy.

Fig. 29. Same as Fig. 26, but more perfect, and heavily encrusted. Station 4721.

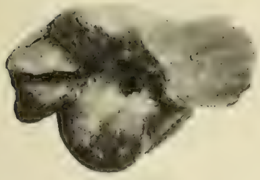
Fig. 30. Right periotic of unknown Delphinoid species, somewhat encrusted. Station 4685.

Fig. 31. Imperfect right tympanic of unknown Delphinoid species, considerably encrusted. Station 4721.

Fig. 32. *Delphinus* sp., somewhat resembling *D. delphis.* Inferior aspect of left tympanic, Station 4740.

Figs. 33-34. *Hyperoodon* sp. ind., Station 4666. Tympanic and periotic belonging to the left side of a single individual.

Figs. 35-36. *Hyperoodon* sp. ind., Stations 4656 and 4676. Right tympanic and left periotic, more or less encrusted, turned to show opposite aspects from Figs. 33 and 34.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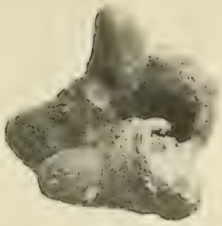
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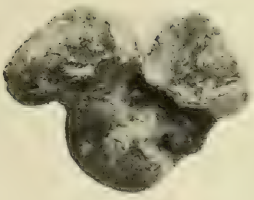
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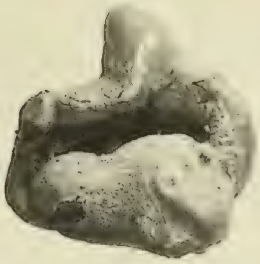
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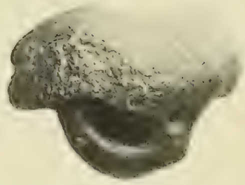
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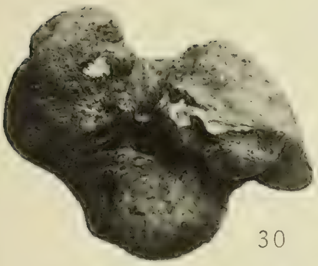
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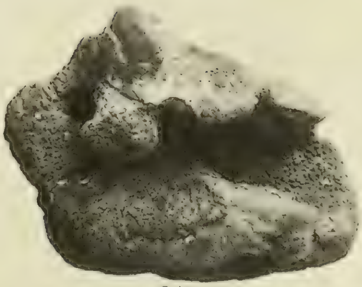
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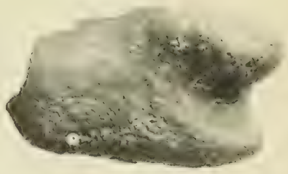
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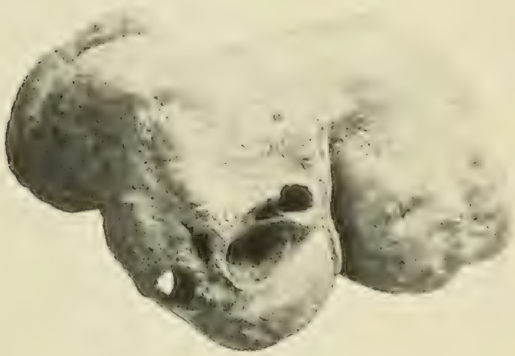
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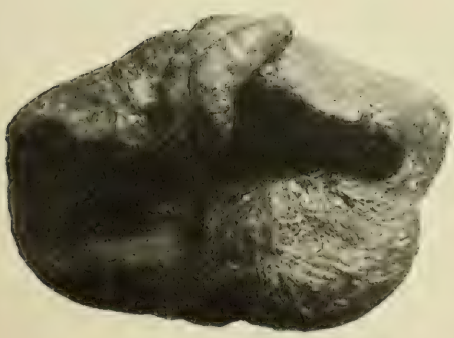
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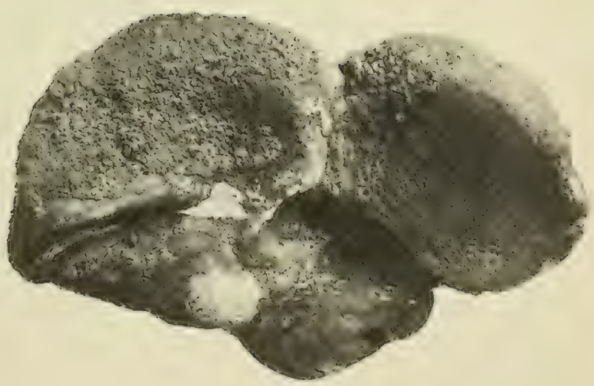
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HELIOTYPE CO., BOSTON.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. L. No. 5.

VERTEBRATA FROM YUCATAN.

INTRODUCTION. AVES.

By Leon J. Cole.

MAMMALIA.

By Glover M. Allen.

REPTILIA; AMPHIBIA; PISCES.

By Leon J. Cole and Thomas Barbour.

With Two Plates.

CAMBRIDGE, MASS., U. S. A.:

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No. 5. — *Vertebrata from Yucatan.*

CONTENTS.

1. INTRODUCTION. By Leon J. Cole.

The following papers upon the vertebrates of Yucatan are based upon collections and notes made by the writer during a visit to that country in the early part of 1904. In addition there have been included several smaller collections from other sources. The trip was made, through the generosity of Mr. Alexander Agassiz, in the interest of the Museum of Comparative Zoölogy. Its primary object was a study of the animal life of certain deep water-holes, or *cenotes*, in the vicinity of the ancient ruined city of Chichen-Itza. The present papers, however, deal almost entirely with collections made independently of that work, since the vetebrate fauna properly belonging to the cenotes is very small, comprising only three or four species of fish, two or three anurans that lay their eggs in the water, and a single species of turtle. Iguanas and other lizards, it is true, find convenient habitations in the rocky walls, while the presence of an abundant supply of water, together with the more luxuriant foliage, attracts to the vicinity numerous birds and other animals which are scattered throughout the forests.

By far the larger part of the collections were made at Chichen-Itza, but some collecting was also done at other places, notably at Progreso. All of the fishes, with the exception of three species, are from the latter locality. In reporting upon the birds, the list for Chichen-Itza has been kept separate, but in the case of the other groups all the specimens obtained have been listed together.

A brief notice of the itinerary may be of interest as showing the periods spent at the different places. The places mentioned are indicated upon the accompanying sketch map of northern Yucatan.

I arrived at Progreso on January 27, where I was kindly received by Mr. E. H. Thompson, the United States consul. Mr. Thompson now owns the large plantation upon which the ruins of Chichen-Itza are situated, and I enjoyed his hospitality while there. As Mr. Thompson was unable to leave Progreso until February 11, I collected during the interval in its vicinity. One day, February 9, was spent at San Ignacio, a small station about ten or twelve miles from the coast, and half way to Merida. On February 11 we went to Merida, and the following morning took the train to Oitas, some ninety or one hundred miles to the

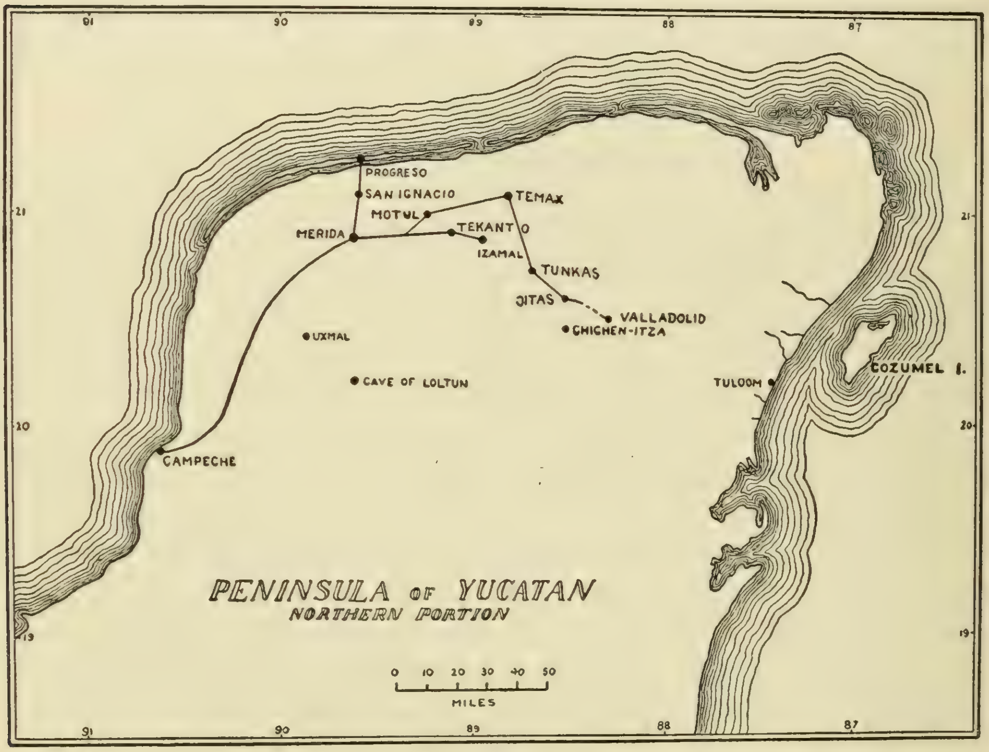


FIG. *A*.

eastward. The railroad is a narrow-gauge line, poorly equipped with modern appliances and conveniences; furthermore, it takes a roundabout course through the principal henequen (so-called "Sisal hemp") growing districts, so that the trip takes nearly a day. Some of Mr. Thompson's Indian servants met us at Oitas with horses, and on the morning of the 13th we rode to Chichen, fifteen or more miles to the southward. I remained at Chichen-Itza from February 13 to April 9. I then returned to Merida, and from there went to Izamal, where I was cordially entertained by Dr. George F. Gaumer, the veteran collector in Yucatan. I had no opportunity to collect at Merida or Izamal.

Further collections were made at Progreso and vicinity from April 12 to 17.

A word should be added as to the general character of the country.[1] The northern part of the peninsula is a soft limestone plain, which slopes gently up to the southward from the Gulf. The rock, in many places bare, is at best covered with only a scanty soil, not capable under the existing conditions of supporting a very luxuriant vegetation. There are no surface rivers, at least none of any permanence, the water sinking quickly into the porous limestone rock and finding its way to the sea by underground courses. There are, however, numerous caves and openings down to the water, which, in the northern part of the peninsula at least, appears to maintain a fairly constant level but little above that of the sea. These water-holes are known locally as *cenotes*.

The western part of the country, in the region of Merida, is largely cleared of the forests and given over to the growing of henequen, the plantations of which sometimes stretch away as far as the eye can reach. To the eastward the land is uniformly forested, except for occasional clearings for the growth of corn or sugar cane. Such is the country about Chichen-Itza, where from the top of one of the ancient ruins which rises above the forest one may look in all directions to the horizon over an almost level and unbroken sea of tree tops. Only here and there is the general level interrupted by a growth of taller trees about a cenote, or where the forest mounts over the crumbled pile of a prehistoric building.

Owing to the porosity of the rock and the scarcity of surface water, the conditions in northern Yucatan are much more arid than would at first thought be expected, and, as might be supposed, this has a noticeable effect upon the fauna. Many of the birds, for example, are distinguished as geographical races, and in nearly all cases this distinction is based upon their being smaller in size and paler in coloration than the representatives of the same species which live in the more humid regions of Mexico and the countries to the southward.

Progreso is situated upon a low-lying strip of sand between the Gulf on one side and an extensive mangrove marsh on the other. This marshy strip, spoken of as *la cienaga*, *el rio*, or *la laguna*, extends along

[1] A good description of the physiographic and climatic conditions of Yucatan may be found in a recent paper by David Casares, A notice of Yucatan, with some remarks on its water supply. Proc. Amer. Antiquarian Soc. for 1905, new ser., 1906, **17**, p. 207–230.

nearly the whole northern coast of Yucatan.[1] It is fed in large part by springs through which the underground water of the interior reaches the surface. Its breadth varies greatly with the season, being much greater during the period of rains. Its waters, which are brackish, abound with small fish, some of which are, however, large enough to be of food value; while birds, especially herons and water fowl, are abundant among the mangroves and on the open stretches. On the sandy costal strip the vegetation is low and scrubby, scarcely higher than one's head, and here small lizards constitute the characteristic faunal element.

At San Ignacio the "brush" is higher, but is not dense. Extensive areas are devoted to henequen growing, and it was in these open places that the Burrowing Owl was found. In many places the rock is bare and weathered, so that the numerous fossil shells imbedded in it stand out at the surface in bold relief. The country about Merida is practically the same.

At Chichen-Itza the forested condition prevails. In general the soil is somewhat thicker, but even here it only thinly covers the underlying rock, which crops out everywhere. The general topography is very flat and level, but is broken up somewhat by the unequal weathering of the rock and the erosion of temporary streams during times of heavy rains. Chapman[2] describes the forest as "a dense scrub of trees and saplings, averaging one and a half to three and a half inches in diameter and fifteen to thirty feet in height." There are, however, not infrequently trees of greater size. Here and there are clearings a few acres in extent where the Indians have established their *milpas* or corn fields. These are made by cutting down the larger trees and leaving them to dry. The place is then burned over at the end of the dry season, and the corn planted upon the approach of the rains. This process is very exhaustive to the soil, and the *milpas* consequently have to be changed frequently to new locations. A dense, scrubby growth, however, immediately springs up on the deserted area.

The cenotes deserve a word of special mention. There are two of these in the immediate neighborhood of the ruins of Chichen-Itza. The Sacred or Sacrificial Cenote is nearly circular in outline, with a diameter of one hundred and ninety feet, while its walls are vertical, and sixty-

[1] For a discussion of the nature and origin of the sandy costal strip and the *cienaga,* see Die Küstenbildung des nördlichen Yukatan, by Arthur Schott. Petermann's Geogr. Mittheilungen, 1886, **12**, p. 127–130.

[2] Chapman, Frank M. Notes on birds observed in Yucatan. Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 271–290.

five feet high from the level of the water to the general surface of the ground. The surrounding forest crowds to the very edge of the cenote, and a scanty vegetation clings to the irregularities of its walls. The water is fresh, is about thirty feet deep, and of a greenish color. The color appears to be due to algal plankton, and not to the depth as many authors have stated. The so-called Great Cenote in reality has a smaller diameter at the water surface than the other, but it appears larger by reason of its sloping walls. These afford lodgement for a vegetation which maintains a luxuriant growth in consequence of the never-failing supply of water.

The cenotes offer an interesting problem in connection with faunal distribution. Although it is maintained by many that they are all a part of a great underground river system, it seems fairly certain that many of them are not connected with the others by definite subterranean streams of any size, but that the general level is maintained rather by "seepage" through the loose, porous rock. Our knowledge of the fauna is as yet too limited to afford much evidence for either view, but such as there is appears to indicate a lack of underground connections of a size sufficient for fish to pass from one cenote to another. This matter is more fully discussed in the introductory remarks to the report on the fishes, and applies to the cenotes at Chichen-Itza; at other places, as at Izamal, there appears to be conclusive evidence of the connection of neighboring cenotes by passages of considerable size.

Although the period of my visit fell in what is the dry season in Yucatan, there was considerable rain, especially during the earlier part of the time. In the latter part of February and early March, heavy showers, frequently accompanied with thunder and lightning, were very common in the middle of the afternoon. During this period the air was usually clear, but on February 19, 20, and 21 there was a considerable fog in the early morning. Except when there were showers, there was nearly always a clear sky with bright sunshine; only a few days during the whole eight weeks were what could be called cloudy. In the latter part of March the weather became considerably warmer and much more typical of the dry season. Nearly every day there was a strong hot wind which seemed to dry up everything it struck. Previously one could always be comfortable when in the shade, so long as there was a breeze; now the hot wind added to one's discomforts. There was also a noticeable change in the animal life, especially the insects. Certain forms which I had not seen before, — such as a large species of fly which was very

troublesome to the horses and cattle, — became common, and the call of Cicadas became a characteristic sound in the forests, whereas not one had been heard before. This is the kind of weather the Indians depend upon for drying their *milpas*, and early in April they began burning them on all sides. The air soon became hazy with smoke, and from the summit of the *Castillo* great ascending columns could be seen in all directions as far as the eye could see.

Field work in Yucatan is made extremely uncomfortable by the abundance, especially in regions where cattle are allowed to run in the woods, of small ticks, locally known as *garrapatas*. These hang in clusters on the bushes and become brushed upon the clothes in countless thousands. Even with the greatest precaution great numbers of them find their way beneath the clothes, where they bury their heads in the skin and cause an irritation which at times becomes almost unbearable. Furthermore, nearly all the mammals and larger birds are covered with them, so that in making up the skins of these animals one receives a further supply of the ticks. The only remedy that was found to be at all efficacious was the free application of kerosene oil. It is said that during the summer months these pests almost, or even completely, disappear.

In conclusion, I cannot express too strongly my sense of indebtedness to both Mr. and Mrs. Thompson for their kindness and hospitality during my stay at Chichen-Itza, and in fact during the whole time that I was in Yucatan. A large room was placed entirely at my disposal, and everything was done that could be to aid my work. Only one who has gone into a strange country where an unfamiliar tongue is spoken can appreciate the advantage of having the constant aid and advice of those familiar with the country and its inhabitants.

2. MAMMALIA. By Glover M. Allen.

Specimens representing twenty species of mammals were obtained by Mr. Cole during his stay in Yucatan. Although none of these appears to be undescribed, several are of considerable interest on account of their rarity in collections. The list follows : —

DIDELPHIDAE.

1. Didelphis yucatanensis Allen.

The single specimen, a male, obtained March 31, 1905, is from the type locality, Chichen-Itza. The measurements taken by Mr. Cole from the fresh specimen are: length, 690 mm.; tail, 315 mm.; hind foot, 56 mm.

DASYPODIDAE.

2. Tatu novemcinctum (Linné).

A single male was secured at Progreso.

TAYASSUIDAE.

3. Tayassu angulatum yucatanense Merriam.

The skin and skull of a male from Chichen-Itza are in the collection, taken March 16, 1905. The measurements from the fresh specimen are: length, 795 mm.; tail, 190 mm.

CERVIDAE.

4. Odocoileus toltecus (Saussure).

Three skulls from Chichen-Itza seem to be referable to this species.

5. Hippocamelus pandora Merriam.

Two skins, one of them accompanied by a skull, were taken at Chichen-Itza. The total length of the female specimen is noted as 1020 mm. The male example measured: length, 970 mm.; tail, 85 mm.; hind foot, 265 mm.

SCIURIDAE.

6. Sciurus yucatanicus (Allen).

A single female was taken, and Mr. Cole notes that but few others were seen, in contrast to Mr. F. M. Chapman's experience in 1896, who found them "common at Chichen-Itza."

MURIDAE.

7. Mus rattus Linné.

A single specimen from Chichen-Itza was preserved.

8. Mus alexandrinus I. Geoffrey.

Two skins with skulls, from Chichen-Itza, are in the collection.

9. Mus musculus Linné.

The house mouse was abundant at Chichen-Itza. Several specimens trapped in the fields were preserved.

GEOMYIDAE.

10. Heterogeomys torridus Merriam.

A skin and skull in the collection, from Xbac, southeast of Izamal, seem referable to this species, though more specimens might show that the peninsular animal is distinct from those of Mexico proper. The specimen was obtained in 1901 by Dr. George F. Gaumer's collector.

HETEROMYIDAE.

11. Heteromys gaumeri Allen and Chapman.

A head of this species, with skull, taken at Chichen-Itza, was preserved.

AGOUTIDAE.

12. Agouti paca virgata Bangs.

A paca's skull was dredged from the Cenote at Chichen-Itza.

LEPORIDAE.

13. Lepus truii Allen.

A female specimen, taken at Chichen-Itza, seems referable to this species.

14. Lepus floridanus yucatanicus Miller.

A male was captured at Chichen-Itza.

CANIDAE.

15. Urocyon cinereoargenteus parvidens Miller.

The type of this subspecies was obtained at Merida, and the specimen secured by Mr. Cole at Chichen-Itza seems referable to it. Undoubtedly this is a small race peculiar to the arid portion of the Yucatan peninsula. The following measurements were taken from the fresh specimen: length, 740 mm.; tail, 281 mm. It was a female, and contained five embryos, March 6, 1904. Another fox, probably of this subspecies, was seen Feb. 9, 1904, at San Ignacio.

VESPERTILIONIDAE.

16. Rhogeëssa tumida H. Allen.

A single female was obtained at Chichen-Itza. I have found no other published records for this species from Yucatan, though its occurrence was to be expected.

MOLOSSIDAE.

17. Molossus nigricans Miller.

Seven specimens, all females, were taken at Chichen-Itza, where they were found in the roofs of dwellings. Miller, in his original description of the species, also records specimens from this locality.

18. Nyctinomops yucatanicus Miller.

A single female was obtained at Chichen-Itza, the type locality of the species.

PHYLLOSTOMATIDAE.

19. Otopterus pygmaeus (Rehn).

An adult male, captured March 5, 1904, at Chichen-Itza, appears to be the second recorded specimen of this very distinct dwarfed species. The type was

from Izamal, Yucatan, and probably represents a species characteristic of this arid portion of the peninsula. The following measurements in millimeters were taken from this specimen, and for comparison, those of the type are added in parentheses, as given in the original description (Rehn, Proc. Acad. Nat. Sci., Phila., 1904, p. 445): ear, 17 (17.2); greatest width of ear, 12.5 (13); tragus, 5 (7); forearm, 35.3 (35.5); thumb, 9.6 (10); third digit, 62.4 (65.5); tibia, 14.1 (14.9); calcaneum, 9.1 (9); foot, 8 (10.5); nose-leaf and pad, 8.3 (7.2); greatest zygomatic width of skull, 9.1 (9.2); extreme length of skull, 19 (—).

20. Artibeus yucatanicus Allen.

A male, taken at Chichen-Itza, the type locality, March 14, 1904, represents this recently recognized species.

3. AVES. By Leon J. Cole.

Mr. Frank M. Chapman, in his Notes on Birds observed in Yucatan,[1] published an excellent list of the birds observed by him at Chichen-Itza, Yucatan, during the month of March (3-21) of the same year. Although much collecting had been done in a general way in the peninsula for many years, so that the bird fauna was comparatively well known, this was the first strictly local list for any part of the country. Until recent years, when the railroads have been much extended, Chichen-Itza was rather inaccessible and difficult to reach; and as a consequence, with a few exceptions, most of the naturalists and collectors who have visited Yucatan have confined their operations to within a comparatively short radius of Merida. As early as 1841 and 1842 Dr. Samuel Cabot, Jr., in company with the explorer Stephens, journeyed over much of the northern part of Yucatan, including in his travels a visit to Chichen-Itza, and even to the island of Cozumel off the eastern coast. Stephens published a brief "Memorandum" of Cabot's results in the second volume of his Incidents of Travel in Yucatan (Harper Brothers, 1843), but with a few exceptions definite localities are not given. The most extensive collecting in the peninsula was done from twenty to thirty years ago by Dr. Geo. F. Gaumer, who is still living at Izamal. Many of his notes were published by Boucard in the Proceedings of the Zoological Society of London, 1883; and in many cases exact localities are mentioned, so that the records have value from a distributional standpoint. His collections, however, went to various persons, though many of them finally came into the hands of Salvin and

[1] Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 271–290. This article includes a good bibliography of the principal papers relating to birds published before 1896.

Godman, and formed the principal material for the notes on Yucatan birds in the Biologia Centralia-Americana. So far as I am aware, there is no specific record of birds collected at Chichen-Itza by Gaumer.

Since Chapman's visit, and previous to my own, Messrs. E. W. Nelson and E. A. Goldman, of the United States Biological Survey, spent a short time at Chichen-Itza, and Nelson has published a number of notes and descriptions of new or rare forms procured by them.

In spite of the remarkable uniformity of the greater portion of the northern part of the peninsula of Yucatan, there is a marked difference in the bird fauna of the costal belt and the interior; and apparently also between those parts of the country where the forests have been very largely cleared away to give room to henequen plantations, and the wilder portions to the eastward, which are still densely wooded. For this reason, as Chapman says, as well as for the information to be obtained regarding migrations and the more casual wanderings of the birds, local lists seem desirable. The present paper is an attempt to make more complete the list of winter birds of Chichen-Itza.

As has been mentioned, my stay at Chichen-Itza covered a period of eight weeks — from February 13 to April 9, 1904. Only a small portion of this time, however, was given to the observation and collection of birds, which was rather incidental to the other collecting. I have already expressed my deep gratitude to Mr. E. H. Thompson for his hospitality, and it gives me pleasure to add that I owe fully as much to him for his interest in my work with the birds. Not only did he give me every information at his command, but by furnishing them with powder and shot, he arranged it so that the Indians on his plantation brought me many birds which I should otherwise probably have been unable to procure. I am also indebted to Mr. Thompson for assistance in obtaining the Maya names of the birds and for the translation and explanation of the meanings of some of these.

Chapman in his paper has given a good description of the character of the country, and something has been added in my general introduction, so that little more need be said here. It is doubtful, however, if the portion to the eastward of the henequen belt has ever been so completely deforested as Chapman believes. It is probable rather that the general low, "scrubby" character of the vegetation is due to the arid conditions of the peninsula — to the thinness of the soil and the porosity of the underlying rock. There are, however, as Chapman says, trees of certain species which attain a considerable size, and especially is this true in the immediate vicinity of the cenotes.

Chapman has also given a discussion of the origin of the Yucatan avifauna, and later researches only tend to confirm his conclusion that it is essentially Central American in its character. Recent explorations have not done much in the way of adding new species, but a number of forms have been split off as varietal. As is to be expected in an arid country, these are in nearly all cases distinguished from their relatives of Mexico, Guatemala, Honduras, and neighboring regions to the southward by their smaller size and paler color.

The weather during the period I spent at Chichen was more rainy than is usual for the dry season, and this may have had some influence on the bird life. But the general aspect was one of winter, or early spring, in spite of the warmth and the occasional flowers. This was emphasized by the fact that many of the birds were to be found in droves or flocks made up of a number of species, much as they are in our own woods in the autumn and winter months. Thus one would often meet with droves of warblers of various species, or of wood hewers, ant thrushes, and the like. The jays, cowbirds, ground doves, parrots, and even flycatchers, were usually in flocks of their own kind, while the hawks, wrens, tanagers, cardinals, and other finches were usually to be found singly or in pairs. Baker apparently found this peculiarity even more marked in the vicinity of Tekanto, for he writes (A Naturalist in Mexico, 1895, p. 32): "While hunting along the narrow path-ways through the forest in the neighborhood of the camp, we would pass several hours without seeing many birds; but now and then the surrounding bushes and trees appeared suddenly to swarm with them. There were scores of birds, all moving about with the greatest activity — Crotophaga, woodpeckers, tanagers, flycatchers, and thrushes, flitting about the lower leaves and branches. The bustling crowd lost no time, but hurried along, each bird occupied on its account in scanning bark, leaf, or twig in search of insects. In a few minutes the host was gone, and the forest remained as silent as before."

The attempt has been made in the present list to include every species of bird known to have been definitely reported from Chichen-Itza, bringing the total number to one hundred and twenty-eight species and subspecies. This is an increase of fifty-four over Chapman's list, which enumerated seventy-four forms. The additions are from four sources: (1) Birds collected or observed by myself; (2) Easily recognizable birds added on the authority of Mr. Thompson; (3) A collection of skins made by Mr. Thompson in the early nineties; (4) Records from other sources. My own collections were made with the idea of obtaining as

representative a series of the birds as possible, so that in most cases only one or two of a species were taken. These are now in the Museum of Comparative Zoölogy. Two birds which seemed unmistakable are included on Mr. Thompson's authority as being at times found at Chichen. These are the Barn Owl (*Strix pratincola*) and the Mexican Road Runner (*Geococcyx affinis*). Others, concerning which there was less certainty, have not been included. The collection of skins mentioned as having been made by Mr. Thompson (with the aid of a native, under his direction) in the early nineties, comprised eighty-four specimens, representing fifty-three species, among which were nine not otherwise known for the locality. Many of these are also, through his generosity, now in the Museum of Comparative Zoölogy. And, finally, there is a single addition depending upon a record found elsewhere — that for the Central American Boatbill collected by Cabot, and mentioned by Stephens.

Chapman lists ten forms for which I have no other records; these are included here for the sake of completeness, but have been enclosed in brackets so that they may be distinguished. All species recorded by Chapman are preceded by an asterisk in order to facilitate comparison of the two lists.

It must be borne in mind that this is essentially a list of the *winter* birds at Chichen-Itza. As has been stated by Chapman, Gaumer, and Baker, there is probably a considerable migration to the southward from northern Yucatan at this time of year, but concerning such migration there is comparatively little definite information at hand. The birds from Mr. Thompson unfortunately, in most cases, bear no data as to the time of year they were collected; but it is not improbable that some of them are to be found at Chichen-Itza only during the summer months, which include the rainy season. In the case of *Columba speciosa* I obtained direct information that it was common in the summer, but was not there in the winter, and it is possible that the same is true of *Claravis pretiosa*, *Pteroglossus torquatus*, and other birds which were not obtained by either Chapman or myself during our visits in the winter months. In fact, I am under the impression that certain species, such as *Merula grayi* and *Megaquisculus major macrourus*, which I saw only during the latter part of my stay, may have been the returning vanguard of these southern migrants.

No systematic effort at collecting or observing birds was made except at Chichen; but in many cases such incidental notes as were made at other places have been added, the locality being given in each case. A

series of fifteen skins, kindly given me by Dr. Gaumer when I had the pleasure of visiting him at Izamal, is included. Most of these, Dr. Gaumer states, were taken at Xbac, his plantation, some distance to the southeast of Izamal; but as no localities were given on the labels, it has seemed best to record them in nearly all cases as from "Yucatan," the more so as several of the records would be very unexpected so far from the coast. In this connection it is worth while, however, to call attention to the relatively large list of water birds now known from Chichen. These birds are apparently casual wanderers there, attracted by the water of the cenotes, and undoubtedly with continued observation over a longer period the list would be greatly extended.

A short additional list has been added, giving a few incidental notes on birds not as yet recorded from Chichen-Itza.

An attempt was made to obtain, so far as possible, the native Maya names of the birds, and these are given for each species for which they could be learned.[1] In the case of the larger forms there was little difficulty, but as might be expected, the smaller and less conspicuous birds were not so well known, and very often the natives appeared not to have different names for distinguishing them, but applied a common name to the whole lot.[2]

[1] For the system of phonetics used in representing the Maya sounds I am indebted to Dr. Alfred M. Tozzer, Instructor in Anthropology in Harvard University, who has spent portions of the past four winters among the Maya Indians in a study of their language and customs. The following "key" will aid in giving an idea of the pronunciation of the words. The equivalent letters given by Beltran de Santa Rosa in his Maya grammar are indicated for the purpose of comparison, since his symbols have usually been employed in part by those who have published Maya names of birds, and are used in the names of many of the Yucatan cities.

Key to the pronunciation of Maya words.

The vowels and consonants have their *continental* sounds, with the following exceptions:

ă like *u* in h*u*t,	š (Beltran *x*) like *sh* in hu*sh*.
ai like *i* in *i*sland,	tš (Beltran *ch*) like *ch* in *ch*urch,
k (Beltran *c*) ordinary palatal *k*,	tṣ̌ (Beltran *cħ*) *tš* explosive,
q (Beltran *k*) velar *k̇* (explosive),	p̣ (Beltran *pp*) *p* explosive,
ɔ̣ (Beltran *ɔ*) *ts*, explosive or fortis,	ṭ (Beltran *th*) *t* explosive.
ɔ (Beltran *tz*) *ts* non-explosive,	Doubled vowels should be doubled in pronunciation.

[2] Some of the Maya dictionaries and vocabularies give the names of a few of the birds, but it is usually difficult, and often impossible, to determine the species meant. Gaumer gave a number of the Maya names in the notes published by Boucard (Proc. Zool. Soc., Lond., 1883), and a few are given also by Norman in his

The "stomach contents" of a considerable number of birds were preserved with the idea of gaining some knowledge of their food. Mr. F. S. Millspaugh, of the Field Columbian Museum, who is probably more familiar with the Yucatan flora than any other botanist, kindly undertook for me the identification, in so far as possible, of the seeds and other parts of plants included in these collections, and his determinations have been inserted in each case under the notes on the species in question. Although they are of interest now only in a general way, it is hoped these observations may be of use when a study of the economic value of these birds is made.

In the identification of the specimens obtained I am very deeply indebted to Mr. O. Bangs, who has also given me much assistance in other ways. Furthermore, I wish to express my thanks to Messrs. E. W. Nelson, Robert Ridgway, and Witner Stone for the examination and comparison of certain of the birds.

LIST OF THE BIRDS OF CHICHEN-ITZA, YUCATAN.

TINAMIDAE.

1. Crypturus sallaei goldmani Nelson.

Proc. Biol. Soc. Wash., 1901, **14**, p. 169.

Yucatan Tinamou.

Maya name, *nom ;* Spanish, *perdiz.*

A single specimen was brought me by the Indians (March 12, 1904). It was so badly mutilated that its sex could not be determined. The species appears to be common over the whole of the northern part of the peninsula (Biol. Centr.-Amer., **3**, p. 456). The type specimen is from Chichen-Itza.

Legs, when fresh, orange.

With regard to the food, as determined from this specimen, Mr. Millspaugh reports:

"This bird is a very heterogeneous seed-eater, with an evident tendency towards selecting those of a euphorbiaceous character. It is particularly noticeable that so few seeds occur of many species that seed largely, the bird strangely selecting but a few of each. The craw contained the following euphorbiaceous seeds: 1 *Tragia nepetaefolia ;* 1 *Croton cortezianus ;* 1 *Dalechampia* species ; 4 *Croton lobatus ;* 2 capsules *Euphorbia astroites* (with ripe

Rambles in Yucatan (New York, 1843). It is very common for the Indians in giving the names of the birds to attach to them the feminine prefix š (Beltran *x*). Thus *pū-hui* (p. 127) becomes *špū-hui ; ṭuuṭ* (p. 125) becomes *šṭuuṭ ; kū-sam′* (p. 134) becomes *škū-sam′; ta-pīn* (p. 142) becomes *šta-pīn,* etc.

seeds); 1 capsule *Tragia nepetaefolia* (with ripe seeds); 7 seeds *Croton* species; 54 seeds *Croton* species; 3 unknown species of seeds (one seed each).

"1 bit of leaf of *Peperomia* species; 1 whole wasp.

"The following verbenaceous species: 1 seed *Tamonea scabra;* 4 seeds *Stachytarpheta jamaicensis;* 1 nutlet, unknown species.

"1 fruiting calyx of some unknown mint; 4 capsules containing 2 seeds of *Henrya costata;* 24 seeds of some unknown acanthaceous species; 3 seeds of *Cedrela ororata;* 1 ripe fruit *Morinda roioc;* 6 seeds some unknown euphorbiaceous plant; 5 seeds some unknown legume; 4 seeds *Heliotropium indicum.*"

CRACIDAE.

2. *Ortalis vetula pallidiventris[1] Ridgway.

Yucatan Chachalacca.

Maya name, *baats̆.*

One specimen: ♀, March 15, 1904.

Chapman mentions hearing these birds calling only in the morning. I heard them more often just at dusk, and only once, when the sky was overcast just before a shower, did I hear one in the middle of the day.

A native in Progreso, the proprietor of a chocolate shop, had two of these birds alive about his place. They were as tame as domestic fowls, and ate bread, cakes, and similar food. I succeeded in purchasing these two birds, intending to take them to the New York Zoölogical Park, but unfortunately only one of them lived to reach there.

MELEAGRIDAE.

3. *Agriocharis ocellata (Cuvier).

Ocellated Turkey.

Maya name, *kuɔ.*

One specimen: ♂, March 30, 1904.

Not infrequently brought in by the Indians, who cook it as they do most of their meat. They place it in a hole in the ground where they have had a fire, and cover it over with banana leaves, then with palm leaves and earth. Even when thus cooked the flesh is delicious.

ODONTOPHORIDAE.

4. *Eupsychortyx nigrogularis (Gould).

Colinus nigrogularis (Gould). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 289.

Yucatan Bob-white.

Maya name, *bets̆.*

Two specimens:

a. ♂, March 4, 1904.

b. ♀, Progreso, Feb. 8, 1904.

[1] All species recorded from Chichen-Itza in Chapman's list are preceded by an asterisk.

This bird occurred in flocks in the clearings of Chichen-Itza, where its call, resembling very closely that of *Colinus virginianus*, was often heard. A single moderate-sized flock was seen among the low growth on the sandy soil near Progreso.

5. Dactylortyx thoracicus sharpei Nelson.

Proc Biol. Soc. Wash., 1903, **16**, p. 152.

Yucatan Long-toed Grouse.

Maya name, *bets̆*.

One specimen: ♀, March 7, 1904.

This subspecies was described from a specimen taken at Apazote, Campeche, by Nelson and Goldman. Mr. Nelson has kindly examined the present specimen for me, and pronounces it typical. Previously specimens had been taken by Dr. Gaumer at Tizimin and at Peto, and he reports it as "equally common in all the eastern forests of Yucatan" (Biol. Centr.-Amer., **3**, p. 309, under *D. thoracicus*).

Mr. Millspaugh reports as follows upon the contents of the craw of this specimen: "This bird evidently feeds almost entirely upon the seeds of euphorbiaceous and leguminous plants. I find: 5 beans from some unknown *Phaseolus*; 40 beans of *Phaseolus semierectus*; 15 seeds of *Dalechampia* species; 4 seeds of *Jatropha* species; 2 seeds of an unknown *Euphorbia*; 1 seed unrecognizable; also about two drachms of the seed coats macerated beyond recognition."

COLUMBIDAE.

6. Columba speciosa Gmelin.

Dr. Gaumer presented me with a skin of this bird, said to have been taken at Xbac in 1901. At Chichen-Itza I saw a live specimen in a cage in an Indian hut, and was told that the bird was taken in that vicinity the previous summer. The Indians say they are not there during the winter months.

7. *Columba flavirostris Wagler.

Red-billed Pigeon.

Maya name, *ku-kut-kīp'*.

Three specimens:

a. ♀, March 5, 1904.
b. Chichen-Itza, 189–, E. H. Thompson (Pablo Perera).
c. Chichen-Itza, 189–, E. H. Thompson.

Bill, feet, and legs red.

Mr. Millspaugh reports: "This craw contains four fruits of some sapotaceous species, possibly a *Chrysophyllum*; one of these fully ripe, the other three immature."

PERISTERIDAE.

8. *Melopelia leucoptera (Linné).

White-winged Dove.

Maya name, *sak-pa-kal'*.

Five specimens:

a. ♂, March 10, 1904.
b. ♀, March 12, 1904.
c. (alcoholic), 1904.
d, e. Chichen-Itza, 189–, E. H. Thompson.

Common. Skin around eye, blue; iris, brick red; feet, bright red.

9. * Columbigallina passerina pallescens (Baird).

Mexican Ground Dove.

Two specimens:

a. Chichen-Itza, 189–, E. H. Thompson.
b. ♂, San Ignacio, February 9, 1904.

Chapman reports this bird as common at Chichen-Itza. I supposed that I had seen both species of Ground Dove there, but find only *C. rufipennis* among my skins. I obtained one specimen (a male) of the present species at San Ignacio, on February 9, and have a specimen from Chichen-Itza in the Thompson collection.

10. * Columbigallina rufipennis (Bonaparte).

Rufous Ground Dove.

Maya name, *mu-kui*.

Five specimens:

a. ♀, Feb. 26, 1904.
b. ♀, March 28, 1904.
c. ♂, April 3, 1904.
d. ♂, April 3, 1904.
e. fledgling, March 28, 1904 (alcoholic).

Very abundant and tame about the yard, garden, and corrals at Chichen.

Two nests of this species were collected on March 28. They were situated in lime trees in the garden, and not over thirty meters from the house. One of the nests was first discovered on March 26, at which time it contained a single egg; on the 28th there were two eggs, both of which were fresh. They are equally rounded at either end, and measure respectively 21.8 mm. × 16 mm., and 22 mm. × 16.5 mm.

The other nest contained a single fledgling. The female, when disturbed, flew to the ground and fluttered away as if wounded. The nest was placed next to the main shaft of the tree on a small branch, at about three meters from the ground. Both nests are about 9 cm. in diameter and 5 or 6 cm. deep. In one (that containing the eggs) the depression is very slight; in the other the cup is rather deep (about 2 cm.), suggesting the possibility that the nest is added to after the eggs are laid. It seems more probable from its appearance, however, that this is an individual variation in construction. Both nests have a foundation of lime or other leaves, the upper part being rather compactly built of small stems, with a little grass and a few rootlets.

The lower part of the crop of the mother of the young bird was hypertrophied, and exuded the secretion known as "pigeon's milk."

Iris of males, yellow.

Mr. Millspaugh reports that the craw of the mother bird contained "200 seeds representing four unknown species of the euphorbiaceous genus *Croton*." With regard to the two males taken on April 3d, he says; "One of the craws contained two large and fully ripe fruits of some cultivated species of Day lily (*Crinum*). These fruits must have been about 1½ inches in diameter, and were completely filled with a multitude of ripe, bony seeds. There were also found under this number: 46 seeds *Tragia nepetaefolia*; 8 seeds *Croton* species; 2 minute seeds of some scrophulariaceous plant; 43 seeds *Croton flavens*; 14 seeds *Croton albidus*; 1 seed *Croton* species; 2 seeds representing two unknown species."

11. Claravis pretiosa (Ferrari-Perez).

Two specimens:

a. ♂, Chichen-Itza, 189–, E. H. Thompson (Pablo-Perera).

b. Chichen-Itza, 189–, E. H. Thompson.

12. * Leptotila fulviventris fulviventris Lawrence.

Leptotila fulviventris brachyptera (Salvad.). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 287.

Leptotila fulviventris (not *brachyptera*) Laur. Salvin and Godman, Biol. Centr.-Amer., **3**, p. 259.

White-fronted Dove.

Maya name, *ɔu-ɔui.*

Two specimens:

a. ♀ (?), March 5, 1904.

b. Chichen-Itza, 189–, E. H. Thompson.

Contents of craw: "six bony nutlets of some unknown species, and 168 seeds of some equally unknown euphorbiaceous plant." — Millspaugh.

Iris yellow; bill black; feet and legs red.

PODICIPEDIDAE.

13. Colymbus podiceps Linné.

Pied-billed Grebe.

One specimen: ♂, Great Cenote, Chichen-Itza, Feb. 19, 1904.

Stone (Proc. Acad. Nat. Sci. Phila., 1890, 1891, p. 202) saw several birds which he supposed to belong to this species swimming in the aguada at Schkolak, but obtained no specimens.

CHARADRIIDAE.

14. Aegialitis vocifera (Linné).

Kildeer.

One was heard on February 22; saw and heard one March 7; heard one March 27. Mr. Thompson, Sr., told me that a short time before I came to

Chichen he quite often saw "a kind of plover" in the corral. These were very likely Kildeer. Stone (Proc. Acad. Nat. Sci. Phila., 1891, 1890, p. 203) took one specimen at Progreso.

15. ? Gallinago delicata (Ord).

Wilson's Snipe.

In my notes I have the following: — March 8. Late this afternoon I saw a snipe fly into the corral. I caught only a glimpse of it and hurried for my gun, but the bird had gone before I could get back. It looked like a Wilson's Snipe, but I could not identify it with certainty.

ARDEIDAE.

16. [* Ardea herodias Linné. Great Blue Heron.]

17. Florida coerulea (Linné).

Little Blue Heron.

One specimen: ♂ (white plumage), Progreso, Feb. 3, 1904.

A little Blue Heron in the adult plumage was shot by an Indian boy at Chichen on March 24, but its skin was not saved. Abundant in the Mangrove swamp back of Progreso. Stone (Proc. Acad. Nat. Sci. Phila., 1891, 1890, p. 203) observed one on the aguada at S[c]hkolak.

18. Canchroma zeledonia Ridgway.

Central American Boatbill.

In the Memorandum for the Ornithology of Yucatan Stephens (Incidents of Travel in Yucatan, 1843, **2**, p. 474) writes: "Of the genus Cancroma one specimen was procured, the cinereous boatbill, which was killed at the senote at Chichen." This bird is said to be common and very tame at Rio Lagartos (Boucard, Proc. Zool. Soc. Lond., 1883, p. 458).

ANATIDAE.

19. Querquedula discors (Linné).

Blue-winged Teal.

Maya name: The Indians at Chichen knew no name for this bird but the Spanish word *pato*, meaning "duck."

One specimen: ♂, Feb. 23, 1904.

Two Blue-winged Teal were seen at the Great Cenote on the above date, and this specimen was secured.

PLOTIDAE.

20. Anhinga anhinga (Linné)

Anhinga, Snake Bird.

One specimen: plumage of ♂, June 18, 1904, E. H. Thompson.

Mr. Thompson took this specimen of Anhinga at the Sacred Cenote and sent

the skin to the Museum of Comparative Zoölogy. The species has been reported at Progreso by Stone (Proc. Acad. Nat. Sci. Phila., 1891, 1890, p. 203).

PELECANIDAE.

21. Pelecanus fuscus Linné.

Brown Pelican.

One was shot by the Indian boys on February 26 from a large tree not far from the house.

CATHARTIDAE.

22. *Catharista urubu (Vieillot).

Black Vulture.

Maya name, *tšōm;* Spanish, *sapilote.*

Chapman found the Black Vulture "somewhat less numerous than the Turkey Vulture," and of the latter he saw only three or four daily. During my stay at Chichen there were large numbers of Black Vultures in the neighborhood of the hacienda at nearly all times. They roosted at night in the large *pitš* trees, and spent much of the day on the ruins of an old church, where they often presented a curious spectacle as they stood with spread wings after a shower. On February 29 forty-five Vultures were counted in the vicinity at one time. They were awaiting their turn at the carcass of a pig lying in one of the corrals and being devoured by two large, ravenous dogs. While one dog feasted the other stood guard, running at and driving away any of the birds that approached too near. When the dogs sighted me they slunk away, and the Vultures immediately pounced upon the carcass. Heretofore the only note I had heard from these birds was a low grunt which they give as they take wing from the ground, but as they were crowding and flapping around the pig, fighting and pushing one another away, I heard them utter a different note, which sounded more like a *squawk.*

On March 5, at the Sacred Cenote, two old Vultures were seen feeding a young one. The young bird was in one of the shelf-like caves about half-way down the vertical wall of the cenote. It was fully half-grown, but still in the down; body brown, head black. Most of the time it remained back out of sight, but came out into view to be fed. On March 15 the young bird stayed out in sight much of the time. It did not seem to have changed much in appearance since it was first seen on March 5.

Stone (Proc. Acad. Nat. Sci. Phila., 1891, 1890, p. 204) reports finding a nest containing eggs of this species near Tekanto about February 15.

23. [*Cathartes aura (Linné.)

Turkey Vulture.

Maya name, *tšak-pul-tšōm.* *Tšak* = red.

Chapman states that he saw three or four Turkey Vultures daily. I often made careful investigation of the Vultures at Chichen, but did not observe this

species there at all. My remembrance is, however, although I find no mention of it in my notes, that both species were observed at Progreso. Stone (Proc. Acad. Nat. Sci. Phila., 1891, 1890, p. 204) says the Turkey Vulture was occasionally seen by him in Yucatan, but was nowhere common.]

FALCONIDAE.

24. Micrastur melanoleucus (Vieillot)

Maya name, *kŏs* or *ĕk-pīp*.

One specimen: ♀, March 1, 1904.

Not uncommon. Usually seen in the vicinity of the cenotes.

25. Asturina plagiata Schlegel.

Gray Buzzard-Hawk.

Maya name, *ī-kŏs*.

Two specimens:

a. ♂, March 24, 1904.

b. ♀, April 1, 1904.

Not uncommon.

Iris dark.

26. *Rupornis ruficauda griseicauda Ridgway.

Rupornis ruficauda (Scl. & Salv.). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 286.

Yucatan Gray-tailed Hawk.

Maya name, *kan-ī-kŏs*. *Kan* = yellow.

Two specimens:

a. ♀, March 28, 1904.

b. ♂, San Ignacio, Feb. 9, 1904.

Like Chapman, I found this hawk not uncommon.

Iris lemon yellow.

27. *Herpetotheres cachinnans (Linné).

Crying Hawk.

Maya name, *kŏs*.

Heard nearly every morning and evening in several directions. Sometimes heard before daylight in the morning and after dusk at night. The usual note is a rather drawn-out cry, much like the human voice in distress; it sounds like "Oh!" at a rather high pitch, and with a slightly falling inflection at the end. This is repeated at short intervals. Occasionally it gives a series of these cries, increasing in pitch and volume somewhat, and becoming slower as it proceeds. It may be represented roughly as follows: —

Oh! Oh!

Oh!

Oh!

Oh!

Stephens (Incidents of Travel in Yucatan, 1843, **2**, p. 470), mentions the taking of this hawk, which he calls the Laughing Falcon, at Chichen by Dr. Cabot, in 1842.

28. *Falco albigularis Daudin.

Falco rufigularis (Daud.). Chapman, Bull. Amer. Mus. Nat. Hist. 1896, **8**, p. 286.

White-throated Falcon.

Maya name, *qī-līs.*

Five specimens :

a. ♀, March 1, 1904.
b. ♀, March 8, 1904.
c. ♂, March 8, 1904.
d. (alcoholic), 1904.
e. Chichen-Itza, 189–, E. H. Thompson.

Two or three of these beautiful little hawks were commonly to be seen about the Sacred Cenote or in the nearby *milpas*. On March 1, Mr. Thompson observed a pair of them mating, but the ova of a female taken that day were still small. In the fresh specimen the skin in front of the eye is orange; the cere is near to chrome yellow.

29. *Cerchneis sparveria (Linné).

Sparrow Hawk.

Maya name, *ī-kŏs.*

Three specimens:

a. ♀ (?), March 19, 1904.
b. (alcoholic), 1904.
c. ♀, San Ignacio, Feb. 9, 1904.

One or more were seen or heard nearly every day.

BUBONIDAE.

30. Asio magellanicus mayensis (Nelson).

Bubo virginianus mayensis Nelson, Proc. Biol. Soc. Wash., 1901, **14**, p. 170.

Yucatan Horned Owl.

Maya name, *tun-ku-lu-tšu.*

Often, especially in the early part of the night, I heard owls hooting, which I think certainly must have been the Yucatan Horned Owl. The note was a loud *hoo-oo-oo, hoo, hoo.* I was unable to obtain any specimens. Mr. Thompson said that he had seen the bird, and that it looked like the Great Horned Owl (*Bubo virginianus*). This bird is known from only the type specimen collected at Chichen-Itza by Nelson and Goldman in 1901.

31. Otus[1] choliba[2] thompsoni,[3] subsp. nov.

Yucatan Screech Owl.

Maya name, *qō'-a-qab'* (means "night talker").

Type.—No. 40099, ♂ ad., Mus. Comp. Zoöl. Chichen-Itza, Yucatan. March 29, 1904. Leon J. Cole.

Co-type.—♀, Chichen-Itza, 1890, E. H. Thompson (Pablo Perera).

Subspecific characters.—Smaller than *O. choliba*, with greater amount of yellowish buffy suffusion, especially on head and neck, and with coarser black markings on under parts.

Description. — Upper parts similar to *O. choliba*, but with a less reddish cast, and more of a light yellowish or creamy buffy suffusion; fuscous markings on shafts of feathers broader, and broken transverse bars coarser and farther apart.

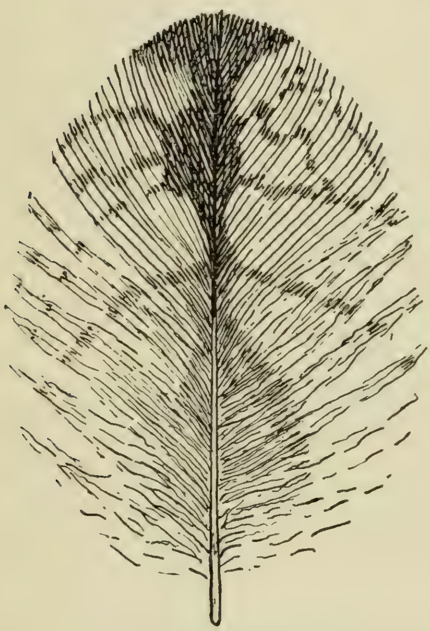


Fig. *B*.

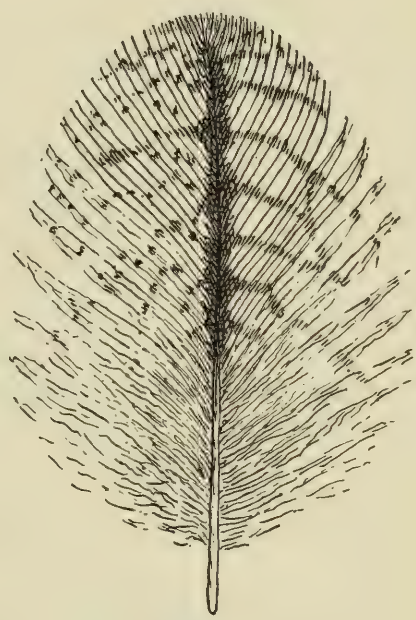


Fig. *C*.

Under parts: Throat suffused with creamy buff; feathers of breast and belly, as on back, with broader central markings, and with coarse and less broken bars. Figure *B* shows a feather from the breast of the type specimen, while Figure *C* represents one of the broadest-streaked feathers from a similar place from a specimen of *O. choliba* taken at Divala, Panama (Coll. E. A. & O. Bangs, No. 7743, ♂ ad., Dec. 11, 1900.) The large markings of these feathers, especially

[1] *Cf.* Stone, Auk, 1903, **20**, p. 272.

[2] It appears that the specific name *choliba* should supersede *brazilianus* (see note by Count von Berlepsch, Bull. Brit. Ornith. Club, 1901, **12**, p. 6).

[3] Named for Mr. E. H. Thompson, United States Consul to Yucatan.

on the breast, are a rich, dark fuscous, edged rather broadly with umber. Lower belly tinged with buffy, giving a richer appearance than that of *O. choliba*. The general tone of the under parts is light, however, *choliba* being more grayish.

Measurements of type.—Wing, 158 mm.; tail, 192; culmen (from base), 20; (from cere), 13; tarsus, 32.

Gray phase.—The specimen described above appears to represent the red phase of this bird, while the gray phase is represented in the specimen taken by a native collector, Pablo Perera, for Mr. E. H. Thompson, at Chichen-Itza in 1890, and marked on the label as a female. This specimen resembles very closely the type, except in lacking, for the most part, the buffy suffusion, and in having a finer reticulation (consisting of more transverse fuscous bars) of the under parts. Measurements: wing, 160 mm.; tail, 84; culmen (from base), 22; (from cere), 13; tarsus, 37.

The single specimen of this owl which I obtained was brought to me by one of the Indians, so that I am unable to give any further notes regarding it. It has been described as new only after having been compared carefully with specimens of *O. choliba* in the U. S. National Museum by Mr. E. W. Nelson, and with a small series in the collection of Messrs E. A. and O. Bangs, by Mr. Outram Bangs and myself. There appears to be more or less of a gradation of the birds of this species in passing from Brazil to southern Mexico. Two specimens in the Bangs collection, from Costa Rica, approach most closely to the Yucatan birds, but lack the clearness of the white which appears in the under parts of the latter.

Salvin and Godman (Biol. Centr.-Amer., **3**, p. 21) report a specimen of "*Scops guatemalae* (which they make synonymous with *Megascops brazilianus* = *O. choliba*) collected by Dr. G. F. Gaumer at Tizimin, Yucatan. It seems reasonable to suppose that this specimen belongs to the Yucatan race, although *Otus guatemalae*, which is undoubtedly distinct from *Otus choliba*, and in a large part co-extensive with it, may really extend northward into the peninsula.

32. *Glaucidium phalaenoides ridgwayi (Sharpe).

Ridgway's Ferruginous Pigmy Owl.

Maya name, *tŏ'-ka-šnuk'*. Literally *tŏ'-ka* means one who picks or pecks stone, *šnuk* is an old woman — the "old woman stone picker." The stones (*metatl*, Mexican; *ka*, Maya) on which corn for *tortillas* is ground are usually roughened by the old women, and the name *tŏ'-ka-šnuk'* is applied to this little owl because its note is supposed to resemble the sound made in the operation.

Three specimens:

a. ♂, Feb. 18, 1904.
b. ♂, March 7, 1904.
c. (alcoholic), 1904.

Common. Apparently largely diurnal in habits. Turns the head with a jerky motion, and also jerks the tail at short intervals. Iris, light yellow.

STRIGIDAE.

33. Strix pratincola Bonaparte.

American Barn Owl.

Maya name, *šotš*.

This species is included in this list entirely upon the authority of Mr. Thompson, who tells me that Barn Owls are sometimes found in the ruins.

PSITTACIDAE.

34. *Conurus aztec Souancé.

Aztec Paroquet.

Maya name, *qa-lī′*. Means "noisy bird."

Three specimens:

a. ♂, Feb. 28, 1904.
b. Chichen-Itza, 189–, E. H. Thompson.
c. ♀, San Ignacio, Feb. 9, 1904.

Abundant. Seen especially mornings and evenings, flying over in small flocks of two or three to several individuals.

35. *Amazona albifrons nana W. DeW. Miller.

Bull. Amer. Mus. Nat. Hist., 1905, **21**, p. 349.

Yucatan White-fronted Parrot.

Maya name, *tuut*.

Three specimens:

a. ♂, March 8, 1904.
b. sex? (skinned from formalin), 1904.
c. Chichen-Itza, 189–, E. H. Thompson.

Small flocks were frequently seen, usually flying rapidly over at morning or evening. The largest single flock observed was composed of 14 birds.

Iris, light straw color.

The craw of the male taken on March 8 was filled with the cotyledons of a leguminous plant which Mr. Millspaugh determined as *Cassia* sp. The bird apparently split the seeds and removed the outer coating before swallowing the cotyledons.

Waldron DeWitt Miller has recently renamed the Yucatan White-fronted Parrot on the ground that it is smaller than the typical *A. albifrons*, with a proportionately larger bill, and more *yellowish* green in color. My birds do not altogether bear out Miller's conclusions, in fact, in measurements they occupy an intermediate position, while the smallest birds I have examined, and the only ones as small as those recorded from Yucatan by Miller, are two specimens in the Bangs collection, from Guatemala. Another specimen taken

farther south, on the boundary between Nicaragua and Honduras, is fully as large as the birds from Yucatan. It is rather hazardous to place much dependence upon size in parrots, but since I have not had opportunity to compare my specimens in other respects with undoubted typical *albifrons* from farther north in Mexico, I have adopted the new subspecific name for the Yucatan birds. It seems not unlikely that the species averages smaller and more yellowish to the southward, though this condition is apparently not limited to the Yucatan peninsula. *A. albifrons saltuensis* Nelson is distinctly different from any other representatives of the species I have had opportunity to examine.

MOMOTIDAE.

36. *Eumomota superciliaris (Swainson).

Red-backed Motmot.

Maya name, *tŏh.*

Two specimens:

a. ♂, Feb. 19, 1904.

b. ♂, March 14, 1904.

These beautiful birds were common, especially about the Sacred Cenote and some of the ancient ruins, particularly the House of the Nuns and the adjacent buildings, where they roosted in the holes in the masonry. At one time several were brought to me alive which had been easily captured in these holes. The time of my visit appeared to be before the nesting season; nevertheless the birds were at times very noisy, their note, which is suggested by the Maya name, being a characteristic sound for the Yucatan forest. Besides the repetition of the single note *tŏh* (or *kwau*, as I have it represented in my notes — the *au* having the sound of *a* in *awl*) they sometimes give a series of notes — *kwau-ka-wa'*, *kwau-ka-wa'*, *kwau-ka-wa'* — which also has more or less variation.[1] They fly with small undulations.

CAPRIMULGIDAE.

37. Chordeiles acutipennis texensis (Lawrence).

Texan Nighthawk.

One specimen: ♂, April 2, 1904.

This bird has been taken at a number of places in Yucatan, but has not previously been reported from Chichen-Itza.

[1] Mr. Thompson says he has recently heard another note of the Motmot — a low, semi-musical series of four notes. The Indians told him it was the *tŏh* that made these notes, but he did not think it could be until he later verified the matter for himself. Sept. 24, 1905.

38. *Nyctidromus albicollis yucatanensis Nelson.

Proc. Biol. Soc. Wash., 1901, **14**, p. 171.

Nyctidromus albicollis merrilli Senn. Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 285.

Yucatan Parauque.

Maya name, *pu-hui*. Said to be an evil spirit that is supposed to swoop down at night and carry people away.

Three specimens:

a. ♂, March 10, 1904.

b. Chichen-Itza, Feb. 5, 1890, E. H. Thompson (Pablo Perera).

c. Chichen-Itza, 189–, E. H. Thompson.

Nelson has recently described the Yucatan Parauque as distinct from Merrill's Parauque (*N. a. merrilli* Senn.), which Chapman considered the Yucatan form to be. Dr. Gaumer (Boucard, Proc. Zool. Soc. Lond., 1883, p. 451) states that this is the "most common of all the Caprimulgidae in Yucatan."

The testes of the male procured by me were very much enlarged (left testis measured 16 mm. × 8 mm.). This would seem to indicate that it was near the breeding season for this bird.

39. Nyctagreus yucatanicus (Hartert) Nelson.

Proc. Biol. Soc. Wash., 1901, **14**, p. 171.

Caprimulgus yucatanicus Hartert, Cat. Birds Brit. Mus., 1892, **16**, p. 575.

One specimen: ♀, March 18, 1904.

So far as I am aware, there is but one previous record of this bird from Yucatan, and that a female taken by Dr. Gaumer on June 10, 1879. On account of the "pure white band across the throat and the white tips to the outer tail-feathers, so frequently characteristic of the male in Caprimulgidae" Salvin and Godman (Biol. Centr.-Amer., **2**, p. 388) were led to doubt whether the sex of this specimen was properly determined. My bird, however, which was undoubtedly a female, possessed these same markings.

40. Antrostomus salvini (Hartert).

Mexican Whippoorwill.

One specimen: ♂, March 29, 1904.

Stated by Gaumer (Boucard, Proc. Zool. Soc. Lond., 1883, p. 451) to be "very common in Merida." Nelson (Proc. Biol. Soc. Wash., 1905, **18**, p. 112) has published the measurements of this specimen as follows: Wing, 176; tail, 130; culmen, 14; tarsus, 18.

CYPSELIDAE.

41. Chaetura gaumeri Lawrence.

Gaumer's Chimney Swift.

Maya name, *kū-sam*.

Three specimens:

a. ♀ March 19, 1904.
b. ♀ March 19, 1904.
c. ♀ March 19, 1904.

Chimney Swifts were first noticed on March 16 and 17, when a number were seen flying about near the house. More were observed on the 19th. They were abundant in the late afternoon, and at about sunset they filed gradually into the vertical well-shaft to roost. On the 19th one of the Indians went down in the well after dark with a lantern and obtained several specimens. The birds were not seen about again until the 23d, and I have no record of them after that date. The note impressed me as rather less loud and harsh than that of *Chaetura pelagica.*

TROCHILIDAE.

42. [*Amazilia yucatanensis (Cabot). Cabot's Hummingbird.]

43. *Amazilia cinnamonea (Lesson).

Cinnamon Hummingbird.
Maya name, *ẹū-nūn.*
One specimen: sex ?, March 29, 1904.

44. *Chlorostilbon caniveti (Lesson).

Canivet's Hummingbird.
One specimen: sex ?, April 7, 1904.

45. [*Lampornis prevosti (Lesson). Prevost's Hummingbird.]

46. Trochilus colubris Linné.

Ruby-throated Hummingbird.
Maya name, *ẹū-nūn.*
Five specimens:

a. ♂, Feb. 4, 1904.
b. [♀], March 23, 1904.
c. [♂], March 25, 1904.
d. [♂], March 27, 1904.
e. [♀], April 5, 1904.

Common. Most of the Hummingbirds seen were of this species.

TROGONIDAE.

47. Trogon puella Gould.

Rayed-tailed Trogon.
Three specimens:

a, b. [♀ ♀], Chichen-Itza, 189–, E. H. Thompson
c. [♂], Chichen-Itza, 189–, E. H. Thompson.

Gaumer (Boucard, Proc. Zool. Soc. Lond., 1883, p. 454) reports this Trogon as very rare in Yucatan.

48. Trogon melanocephalus Gould.

Black-headed Trogon.

Maya name, *kuš-tīn.*

Five specimens:

a. ♀, March 19, 1904.

b. ♂, March 23, 1904.

c–e. Chichen–Itza, 189–, E. H. Thompson.

The yellow on the ventral parts of the specimens taken by me is decidedly paler than in examples from Mexico and Central America with which they were compared, and the white band below the black of the breast is rather broader. The three birds from the Thompson collection, however, are typical. It is possible that the differences noted above may be seasonal, but as the Thompson birds bear no date this cannot be determined from the specimens in hand.

Eye-lids of recently killed bird, light azure blue.

49. Trogon caligatus Gould.

Booted Trogon.

Maya name, *kuš-tīn.*

Six specimens :

a. ♀, March 5, 1904.

b. [♂], March 18, 1904.

c–f. Chichen-Itza, 189–, E. H. Thompson.

Occasionally seen around the Great Cenote.

CUCULIDAE.

50. Piaya cayana thermophila (Sclater).

Long-tailed Cuckoo.

Maya name, *kīp-tšo'.*

Four specimens :

a. ♂ (?), Feb. 28, 1904.

b. ♂ (?) March 4, 1904.

c. (alcoholic), 1904.

d. Chichen-Itza, 189–, E. H. Thompson.

Not uncommon. I am surprised that Chapman did not note this bird.

Iris red.

51. Geococcyx affinis Hartlaub.

Mexican Road runner.

Maya name, *kūm-kūmīl.* " 'Xcum–kumil' is its name in Western Yucatan ; in the East the Indians call it 'Bochen–choo–lool,' " Boucard, Proc. Zool. Soc. Lond., 1883, p. 454.

One specimen: ♂, Yucatan (Xbac?), 1901, G. F. Gaumer.

I include this bird in the list for Chichen-Itza on the authority of Mr. Thompson, who knows the bird well and has seen it there. Dr. Gaumer kindly presented me with a specimen taken by his collector, presumably at Xbac.

52. *Crotophaga sulcirostris Swainson.

Groove-billed Ani.

Maya name, *tšik-bul.*

Two specimens:

a. ♀, Feb. 20, 1904.

b. Chichen-Itza, 189–, E. H. Thompson.

Abundant, especially about the yard and corrals. This species was seen at San Ignacio, also, but was not observed at Progreso, although it is reported from there by Stone (Proc. Acad. Nat. Sci. Phila., 1891, 1890, p. 205).

RHAMPHOSTIDAE.

53. Pteroglossus torquatus (Gmelin).

Collared Toucon.

One specimen: Chichen-Itza, 189–, E. H. Thompson.

PICIDAE.

54. *Melanerpes dubius (Cabot).

Uxmal Woodpecker.

Maya name, *tše-hot* or *tše-hom.*

Four specimens:

a. ♀, Feb. 20, 1904.

b. (alcoholic), March 6, 1904.

c. d. Chichen-Itza, 189–, E. H. Thompson.

Rather common. Note a complaining *chick-r-r-r, chick-r-r-r.*

55. *Melanerpes rubiventris (Swainson).

Swainson's Woodpecker.

Three specimens:

a, b. Chichen-Itza, 189–, E. H. Thompson.

c. Yucatan (Xbac?), 1901, G. F. Gaumer.

Chapman found this Woodpecker "tolerably common" at Chichen, but I did not see it there.

56. [*Dryobates scalaris parvus Ridgway. Cabot's Woodpecker.]

57. Veniliornis caboti (Malherbe).

Chloronerpes oleagineus (Licht.). Boucard, Proc. Zool. Soc. Lond., 1883, p. 452.
Dendrobates caboti (Malh.). Salvin and Godman, Biol. Centr.-Amer., **2**, p. 438.

Maya name, *tše-hot;* also called *tši-piš.*

One specimen: ♀, March 13, 1904.

Not common; Gaumer (Boucard, Proc. Zool. Soc. Lond., 1883, p. 452) gives it as "very rare" in Yucatan. In the specimen taken by me the under side of the wings is unspotted, a condition which Mr. Nelson thinks is due to immaturity.

58. *Ceophloeus scapularis (Vigors).

Delattre's Woodpecker.

Maya name, *ko-lon-te'*. Means "master carpenter"; so called because the largest.

One specimen: ♂, March 23, 1904.

Not uncommon. Iris white.

FORMICARIIDAE.

59. *Thamnophilus doliatus mexicanus Allen.

Mexican Ant-thrush.

Maya name, *ta-ta-tšel*. This name appears to be applied only to the female; the same name is given to Sittasomus and Dendrornis.

Three specimens:

a. ♂, March 11, 1904.
b. ♀, March 12, 1904.
c. sex ?, Yucatan (Xbac ?), 1901, G. F. Gaumer.

Like Chapman I found this bird not common. Iris of male yellowish; not noted in the female.

DENDROCOLAPTIDAE.

60. Synallaxis erythrothorax Sclater.

One specimen: Chichen-Itza, 189–, E. H. Thompson.

Gaumer (Boucard, Proc. Zool. Soc. Lond., 1883, p. 449) gives the Maya name of this bird as "Tzapatan" (*ɔa-pa-tan*).

61. *Dendrocincla anabatina typhla Oberholser

Proc. Acad. Nat. Sci. Phila., 1904, p. 452.

Wood Hewer.

One specimen: Chichen-Itza, 189–, E. H. Thompson.

The marked paleness of this specimen was noticed before it was compared with Oberholser's description of the subspecies. It would appear to be a characteristic condition of the Yucatan birds.

62. *Dendrocincla homochroa (Sclater). Wood Hewer.

63. Sittasomus sylvoides Lafresnaye.

Maya name, *ta-ta-tšel*. Refers to its working about wood; the *ta-ta* is in imitation of the tapping sound made with the bill.

Two specimens:

a. ♀, March 23, 1904.

b. Chichen-Itza, Feb. 5, 1890, E. H. Thompson (Pablo Perera).

Not common. The specimen taken by me appeared to be rather small and pale, but Mr. Nelson, who examined it, writes: "A number of specimens of Sittosomus in our collection from Yucatan show that the birds from that region are not distinguishable from those from elsewhere in Mexico." Specimen *b* agrees with my specimen in coloration, but is a little larger.

64. * Dendrornis flavigastra (Swainson).

Wood Hewer.

Maya name, *ta-ta-tšēl.*

Five specimens:

a. ♂, Feb. 18, 1904.

b–e. Chichen-Itza, 189–, E. H. Thompson.

Chapman reports this bird as "tolerably common," but I found it rather scarce.

TYRANNIDAE.

65. Rhynchocyclus cinereiceps (Sclater).

One specimen: ♀, March 23, 1904.

66. *Myiozetetes similis superciliosus (Bonaparte).

Myiozetetes texensis (Giraud). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 283.

Maya name, *ta-kai'.*

Two specimens:

a. ♂, March 13, 1904.

b. ♂, March 23, 1904.

67. * Megarhynchus pitangua mexicanus (Lafresnaye).

Megarhynchus pitangua (Linné). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 283.

Mexican Large-billed Tyrant.

Maya name: Boucard (Proc. Zool. Soc. Lond., 1883, p. 448) gives the Maya name of this bird as "Stachi." Without the feminine prefix it should probably be written *ta-tšai'* or *ta-kai'*.

Two specimens:

a. ♂, March 14, 1904.

b. Chichen-Itza, 189–, E. H. Thompson

Rather common near the Sacred Cenote.

68. *Empidonax minimus (W. M. and S. F. Baird).

Least Flycatcher.

Two specimens:

a. ♂, Feb. 16, 1904.

b. ♂, April 5, 1904.

Frequently seen and occasionally heard.

69. [*Contopus brachytarsus (Sclater). Short-legged Pewee.]

70. Blacicus depressirostris (Ridgway).

One specimen: ♂, April 5, 1904.

71. [*Myiarchus cinerascens (Lawrence). Ash-throated Flycatcher.]

72. *Myiarchus yucatanensis Lawrence.

Yucatan Crested Flycatcher.

Maya name, *ī'-a*.

Two specimens:

a. ♂, Feb. 18, 1904.

b. sex ?, March 9, 1904.

73. *Tyrannus melancholicus couchi (Baird).

Tyrannus melancholicus Vieill. Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 284.

Couch's Kingbird.

Maya name, *ta-kai'*. Given as "Stachi" by Boucard (Proc. Zool. Soc. Lond., 1883, p. 448.)

Two specimens:

a. ♂, Feb. 22, 1904.

b. Chichen-Itza, 189–, E. H. Thompson.

This bird has a note which reminds one somewhat of the *chip, chip* of a song-sparrow, but it is not so harsh.

COTINGIDAE.

74. *Tityra semifasciata (Spix).

Tityra personata Jardine & Selby. Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 284.

Mexican Tityra.

Maya name, *pē-lan-qē-wel*.

Four specimens :

a. ♂, Feb. 26, 1904.

b. (alcoholic), 1904.

c, d. Chichen-Itza, 189–, E. H. Thompson.

Rather common in the large trees in the clearing near the house.

75. Platypsaris aglaiae (Lafresnaye).

Rose-throated Becard.

Maya name, *ī′-a*.

Two specimens :

a. ♀ (?), March 12, 1904.

b. ♂, March 14, 1904.

76. Pachyrhamphus major itzensis Nelson.

Proc. Biol. Soc. Wash., 1901, **14**, p. 173.

Yucatan Pachyrhamphus.

Two specimens:

a. ♂, March 13, 1904.

b. ♂, Feb. 5, 1890, E. H. Thompson (Pablo Perera).

Apparently rare; but the one specimen seen by me. The subspecies was described from a female taken at Chichen-Itza by Nelson and Goldman.

HIRUNDINIDAE.

77. Progne chalybea chalybea (Gmelin).

Gray-breasted Martin.

Maya name, *kū-sam′*; also *ī-ya′*. "When anything comes near them they circle about it crying '*ī-ya′*, *ī-ya′*,' meaning 'Look out! Look out!'"

Two specimens:

a. ♂, March 4, 1904.

b. ♀, March 4, 1904.

A few of these birds were seen about in the neighborhood of the house in the early part of March. They often flew into holes under the veranda roof to roost.

78. *Stelgidopteryx ridgwayi Nelson.

Stelgidopteryx serripennis (Aud.). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 278.

Maya name, *kū-sam′*.

One specimen: sex ?, Feb. 22, 1904.

Like Chapman, I found these birds abundant about the ruins.

MUSCICAPIDAE.

79. *Polioptila caerulea mexicana (Bonaparte).

Polioptila caerulea (Linné). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 276.

Mexican Gnatcatcher.

Maya name: I did not learn any native name for the Gnatcatcher at Chichen-Itza. Mr. Thompson tells me that at Ticul it is called *ɔī-ɔīl*.

The gnatcatchers which were heard and seen commonly during the whole of my stay at Chichen are probably to be referred to this subspecies. Mr. Bangs states, however, that he believes both *P. caerulea mexicana* and *P. caerulea caerulea* may occur in Yucatan. He has in his collection a fine skin of true *P. c. caerulea* from there identified by Mr. Nelson. Such being the case, it is possible that Chapman's record should not be included under the subspecies *mexicana*.

TROGLODYTIDAE.

80. *Pheugopedius maculipectus cano-brunneus (Ridgway).

Yucatan Spotted-breasted Wren.

Maya name, *pō-kĭm'*.

Two specimens:

a. ♂, Feb. 26, 1904.

b. Chichen-Itza, 189–, E. H. Thompson.

Rather common.

81. *Thryomanes albinucha (Cabot).

Cabot's Wren.

Maya name, *pō-kĭm'*; also *yam-kō-tīl'*. This second name was also applied to warblers and other inconspicuous small birds.

One specimen: sex ?, Feb. 28, 1904.

Common.

82. *Nannorchilus leucogaster brachyurus (Lawrence).

Hemiura brevicauda (Lawr.). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 277.

Temax Wren.

Maya name, *tš-hōt'*.

One specimen: ♀, Feb. 18, 1904.

Common. I occasionally heard a song much like that of *Troglodytes aëdon*, which, from Chapman's remarks, I attribute to this bird.

TURDIDAE.

83. Merula grayi (Bonaparte).

Gray's Thrush.

Maya name, *qōq*. Spanish name, *Ruiseñor*.

Two specimens :

a. ♂, March 31, 1904.

b. Chichen-Itza, 189–, E. H. Thompson.

Iris reddish brown.

The only specimen of this bird observed was taken at about sunset, when it was singing a varied song, somewhat resembling that of the Brown Thrasher ; not loud, but very pretty. Gaumer stated in his notes published by Boucard (Proc. Zool. Soc. Lond., 1883, p. 439) : "It utters no cry when approached, and is said to sing only in June. Though I have spent the summer in Yucatan, I have never had the pleasure of hearing this bird sing." Mr. Thompson confirms his statement that it is often kept as a cage-bird, and adds that it tames easily and breeds in confinement.

VIREONIDAE.

84. Vireosylva olivacea (Linné).

Red-eyed Vireo.

One heard singing on April 3.

85. Vireosylva flavoviridis flavoviridis Cassin.

Yellow-green Vireo.

One specimen : ♂, April 3, 1904.

Iris red.

86. *Lanivireo flavifrons (Vieillot).

Yellow-throated Vireo.

One specimen : ♀, Feb. 18, 1904.

This was the only example of this species noted.

87. *Vireo noveboracensis noveboracensis (Gmelin).

White-eyed Vireo.

Three specimens :

a. ♂, March 6, 1904.

b. (alcoholic), 1904.

c. Chichen-Itza, 189–, E. H. Thompson.

The male taken on March 6 was singing.

88. *Vireo ochraceus Salvin.

Ochraceus Vireo.

Two specimens :

a. ♀, March 23, 1904.

b. ♂, April 7, 1904.

Iris brown.

An Indian working about the yard brought me, on April 7, the male bird recorded above, which he had caught on the nest. The latter, which is deeply

cupped, was situated about 0.5 m. from the ground in a lime hedge, hung in a small crotch. It much resembles in appearance the nest of *Vireosylva olivacea;* rather compactly constructed of small dead leaves, dried grass, and other vegetable fibres, and lined with very fine grass. There are also in the outer part a few pieces of moss and one or two small fungi, while some web-like material appears to have been used to bind the other constituents together. Internal diameter at top 4 cm. × 4.5 cm., somewhat larger below; depth of cup 4 cm.; thickness of walls nearly 1 cm. This nest contained three eggs, which were saved, but cannot now be found. My remembrance of them is that they were white with brownish markings, much resembling the eggs of *Vireo noveboracensis.* Small embryos were already formed at the time they were taken.

89. *Cyclarhis flaviventris yucatanensis Ridgway.

Yucatan Pepper-shrike.

One specimen: ♂, March 30, 1904.

The beautiful clear song of this bird was quite frequently heard.

CORVIDAE.

90. *Cissolopha yucatanica (Dubois).

Yucatan Jay.

Maya name, *tseel* ("Chel," Boucard, Proc. Zool. Soc. Lond., 1883, p. 446).

Six specimens:

a. ♀, Feb. 15, 1904.
b. ♂, April 3, 1904.
c–f. Chichen-Itza, 189–, E. H. Thompson.

Abundant, usually in large flocks. Their habits, when approached, are well described by Gaumer (Boucard, Proc. Zool. Soc. Lond., 1883, p. 446).

91. *Xanthoura luxuosa guatemalensis (Bonaparte).

Guatemalan Green Jay.

Maya name, *sĕ-sīp'*. "The natives call this bird 'jisip' (tzee-seep), which with the Maya pronunciation is exactly the word articulated by the bird." — Boucard, Proc. Zool. Soc. Lond., 1883, p. 447.

Four specimens:

a. ♂, March 7, 1904.
b, c. (alcoholic), 1904.
d. Chichen-Itza, 189–, E. H. Thompson.

Rather common. Iris, yellow; inside of mouth, black.

92. *Psilorhinus mexicanus vociferus (Cabot).

Yucatan Brown Jay.

Maya name, *paap*. From call note.

Two specimens:

a. ♀, March 8, 1904.

b. Chichen-Itza, 189–, E. H. Thompson.

My observations on the occurrence of this bird agree with Chapman's, viz., "Rather uncommon. It was found in pairs and trios in the woods, and was rather shy and suspicious."

MNIOTILTIDAE.

93. *Setophaga ruticilla (Linné).

American Redstart.

Two specimens:

a, b. Chichen-Itza, 189–, E. H. Thompson.

One seen February 18 in a flock of warblers along the road to Xmakaba.

94. *Wilsonia mitrata (Gmelin).

Sylvania mitrata (Gmel.). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 278.

Hooded Warbler.

Four specimens:

a. (alcoholic), 1904.

b–d. Chichen-Itza, 189–, E. H. Thompson.

95. *Granatellus sallaei boucardi Ridgway.

Boucard's Red-breasted Chat.

Maya name, *ťsak-sīn-kīn*: Means "red sun bird."

Three specimens:

a. ♂, March 14, 1904.

b. Chichen-Itza, 1890, E. H. Thompson (Pablo Perera).

c. Chichen-Itza, 189–, E. H. Thompson.

Apparently rare, as only one specimen was observed.

96. *Icteria virens virens (Linné).

Yellow-breasted Chat.

Two specimens:

a. (alcoholic), 1904.

b. ♂, Chichen-Itza, 1890, E. H. Thompson (Pablo Perera).

97. *Geothlypsis trichas brachidactyla (Swainson).

Geothlypsis trichas (Linné). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 277.

Northern Yellow-throat.

One seen in a *milpa* near the Sacred Cenote on February 27, and another along the Xmakaba road on February 28. No specimen was taken, but it is probable that these birds belonged to this subspecies (*cf.* Ridgway, Bull. 50, U. S. Nat. Mus., 1902, **2**, p. 665).

98. [*Seiurus aurocapillus (Linné.) Ovenbird].

99. Dendroica palmarum palmarum (Gmelin).

Palm Warbler.

One specimen: ♂, Feb. 22, 1904.

Gaumer reported this bird from Progreso (Boucard, Proc. Zool. Soc. Lond., 1883, p. 441), and in a note Salvin remarked that that was the first time it had been observed in Central America.

100. Dendroica dominica albilora Ridgway.

Sycamore Warbler.

Two specimens:

a. ♀, Feb. 25, 1904.

b. Chichen-Itza, 189–, E. H. Thompson.

My specimen was taken in an orange tree in the yard.

101. *Dendroica virens (Gmelin).

Black-throated Green Warbler.

One specimen: Chichen-Itza, 189–, E. H. Thompson.

I observed two of these birds at the Sacred Cenote on February 14, and several in a scattered flock of miscellaneous warblers along the Xmakaba road on February 18.

102. Dendroica maculosa (Gmelin).

Magnolia Warbler.

One specimen: sex ?, Feb. 18, 1904.

From a flock of Warblers of various species. This bird has been taken by Gaumer at Izamal (Salvin and Godman, Biol. Centr.-Amer., **1**, p. 129).

103. Dendroica bryanti bryanti Ridgway.

Bryant's Yellow Warbler.

Two specimens:

a. ♂, March 23, 1904.

b. ♂, Progreso, 1904.

104. Compsothlypis americana ramalinae Ridgway.[1]

Western Parula Warbler.

One specimen: ♂, Feb. 18, 1904.

Shot from a flock of miscellaneous warblers.

105. *Mniotilta varia (Linné).

Black and White Warbler.

Two specimens:

[1] Mr. Bangs has in his collection a specimen of *C. a usneae* from Yucatan.

a. (alcoholic), March 13, 1904.
b. Chichen-Itza, 189–, E. H. Thompson.

A few individuals occasionally seen.

ICTERIDAE.

106. Icterus mesomelas mesomelas (Wagler).

Yellow-tailed Oriole.

One specimen: Chichen-Itza, 189–, E. H. Thompson.

107. *Icterus auratus Bonaparte.

Orange Oriole.

Maya name, *yū-yūm.* "Swinging bird."

One specimen: [♂], March 19, 1904.

108. *Icterus giraudii Cassin.

Giraud's Oriole.

Two specimens:

a, b. Chichen-Itza, 189–, E. H. Thompson.

Although I found orioles abundant at Chichen, I did not myself secure a specimen of this species. This was probably due to the difficulty of distinguishing the different species in the field, since *I. giraudii* would appear to be common there.

109. Icterus cucullatus igneus Ridgway.

Fiery Oriole.

Maya name, *yū-yūm.*

One specimen: ♂, Feb. 16, 1904.

110. *Icterus gularis yucatanensis Berlepsch.

Yucatan Oriole.

Maya name, *yū-yūm.*

Three specimens:

a. ♂ March 13, 1904.
b, c. Chichen-Itza, 189–, E. H. Thompson.

111. Icterus prosthemelas (Strickland).

Lesson's Oriole.

Maya name, *hom'-šan-īl'*, meaning "of the palms."

Two specimens:

a. ♀ (juv.), March 13, 1904.
b. Chichen-Itza, 189–, E. H. Thompson.

This appears to be the first record of this species from Yucatan.

112. *Dives dives (Lichtenstein).

Pueblo Blackbird.

Maya name, *pīts̆*. "Native name 'Pich' (pronounced 'peach')" — Boucard, Proc. Zool. Soc. Lond., 1883, p. 446.

One specimen: ♂, March 23, 1904.

Rather common about the hacienda.

113. Megaquiscalus major macrourus (Swainson).

Great-tailed Grackle.

Maya name, *qa͡au*. "Native name 'Sacoa.' The female is considered by the natives another species and is called 'Socao,' instead of 'Sacoa.'" — Boucard, Proc. Zool. Soc. Lond., 1883, p. 446.

One specimen: ♀, April 1, 1904.

114 *Tangavius aeneus involucratus (Lesson).

Callothrus robustus (Cab.). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 280.

Red-eyed Cowbird.

Maya name, *ɔīv*. From call note.

One specimen: ♂, March 4, 1904.

Abundant in the corrals, where they could often be seen climbing over the cattle, horses, and pigs in search of ticks. They sometimes sustain themselves suspended on the wing for a moment or so while they pick ticks from the legs or bellies of the cattle.

115. *Amblycercus holosericeus (Lichtenstein).

Prevost's Cacique.

One specimen: Chichen-Itza, 189–, E. H. Thompson.

Chapman gives this species as tolerably common in and about the borders of the cornfields or *milpas*. I did not observe the bird, and the only specimen from Chichen I have examined is that recorded above.

TANAGRIDAE

116. Phoenicothraupis salvini peninsularis Ridgway.

Yucatan Ant Tanager.

Maya name, *ba-ka-lar′*.

Three specimens:

a. ♂, March 9, 1904.

b. [♀], March 9, 1904.

c. Chichen-Itza, 189–, E. H. Thompson.

117. [*Phoenicothraupis rubica nelsoni Ridgway.

Rosy Ant Tanager.

Phoenicothraupis rubicoides (Lafr.). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 279.]

118. *Piranga roseo-gularis roseo-gularis Cabot.

Rose-throated Tanager.
Maya name, *ba-ka-lar′*.
Five specimens:
a. [♀], Feb. 18, 1904.
b. ♂, March 13, 1904.
c. ♀, March 13, 1904.
d. ♂, Chichen-Itza, Jan. 20, 1890, E. H. Thompson (Pablo Perera).
e. Chichen-Itza, 189–, E. H. Thompson.

119. *Euphonia hirundinacea Bonaparte.

Bonaparte's Euphonia.
Maya name, *tšīn-tšīn-bakal de capa*. The Spanish words *de capa* are added to the Maya name of this species by the Indians to denote the black crown.
Four specimens:
a. ♂, Feb. 20, 1904.
b. ♂, March 13, 1904.
c. ♀, March, 19, 1904.
d. Chichen-Itza, 189–, E. H. Thompson.

Usually keeps well to the tops of tall trees. Note a rather insect-like *chick-che-e-e-e*.

120. Euphonia affinis (Lesson).

Lesson's Euphonia.
One specimen: Chichen-Itza, 189–, E. H. Thompson.

FRINGILLIDAE.

121. * Saltator atriceps atriceps Lesson.

Black-headed Saltator.
Maya name, *ta-pīn*.
Four specimens:
a. ♂, Feb. 27, 1904.
b. ♀, March 9, 1904.
c. ♂, Chichen-Itza, Feb. 10, 1890, E. H. Thompson (Pablo Perera).
d. Chichen-Itza, 189–, E. H. Thompson.

Apparently rather local, as I saw it only in one or two vicinities, not far from the house. Seems to prefer the lower growth on the borders of clearings.

122. *Cardinalis cardinalis yucatanicus Ridgway.

Yucatan Cardinal.
Maya name, *tšak-ɔī′-ɔī*. Means "red painted [bird]."
One specimen: ♀ (?), Feb. 22, 1904.

Common. Chapman says: "In notes and habits this subspecies resembles *C. cardinalis*, but its brighter coloration is evident even at a distance." My observations agree with his in regard to coloration, and so far as I could ascertain, also as to habits; but the song impressed me as markedly different from the clear ringing whistle of *C. cardinalis* as I am familiar with it in our northern States and in Bermuda. The note of the Yucatan bird seems to me to be harsher and less musical, and to be uttered rather more rapidly. In my note book I have it represented as follows:

ch–ch–weé, *ch–ch–weé* (two to four times), *pleu*, *pleu*, *pleu*, *pleu*, *pleu* (five to eight times). There is much variation from this; for example, sometimes only the first three or four notes are given and not followed by the second part of the song.

123. Zamelodia ludoviciana (Linné).

Rose-breasted Grosbeak.

One specimen: (plumage of ♀) Chichen-Itza, 189–, E. H. Thompson.

124. Guiraca caerulea caerulea (Linné).

Blue Grosbeak.

One specimen: (plumage of ♂ in winter), Chichen-Itza, 189–, E. H. Thompson.

125. Cyanocompsa parellina parellina (Bonaparte).

Blue Bunting.

Six specimens:

a. ♂, Chichen-Itza, 1890, E. H. Thompson (Pablo Perera).

b–e. (2 in plumage of ♂, 2 in plumage of ♀), Chichen-Itza, 189–, E. H. Thompson.

f. (plumage of ♂), Xbac (?), 1901, G. F. Gaumer.

126. * Cyanospiza ciris (Linné).

Passerina ciris (Linné). Chapman, Bull. Amer. Mus. Nat. Hist., 1896, **8**, p. 279.

Nonpareil; Painted Bunting.

One specimen: Chichen-Itza, 189–, E. H. Thompson.

127. * Arremonops verticalis Ridgway.

Arremonops rufivirgata striaticeps Ridgw. Chapman, Bull, Amer. Mus. Nat. Hist., 1896, **8**, p. 280.

Schott's Sparrow.

One specimen: ♂, March 19, 1904.

Chapman reports this bird as abundant and "generally distributed in the undergrowth about the borders of clearings, where they pass much of their time on the ground." I found the bird not uncommon, but hardly abundant,

and from the fact that I frequently heard the song in a few definite localities, I judged that the birds might be nesting. They were heard singing as early as March 6, and were still in song when I left, early in April. As Chapman says, the song suggests that of the Field Sparrow. It differs, however, not only in quality, but in keeping about on the same note, and in decreasing but little in volume, though it becomes much more rapid towards the end. It may be represented by the syllables : *chew——chew——chew——chew—che–che–che–che–che–che–che.* When one is close to the singer, a sharp preliminary note may sometimes be heard, thus : *chip, chew——chew——*etc. There appears to be considerable variation in the song of the same individual. The song is usually heard in the early part of the forenoon.

128. Pooecetes gramineus gramineus (Gmelin).

Vesper Sparrow.

One specimen : ♀, April 4, 1904.

So far as I can learn, the Vesper Sparrow has not previously been reported from Yucatan; in fact, this appears to be the extreme southern record for this subspecies, since Salvin and Godman (Biol. Centr.-Amer., **1**, p. 383) state that the bird which occurs in Mexico is the western subspecies, *P. g. confinis.* Ridgway (Bull. 50, U. S. Nat. Mus., 1901, **1**, p. 183) says that it goes "south in winter to Gulf coast (Florida to eastern Texas)." This record is the more remarkable for the lateness in the season when the specimen was taken, the species usually being by that time well north on its spring migration.

The identification of this bird was kindly verified by Mr. Ridgway.

ADDITIONAL LIST OF BIRDS FROM YUCATAN WHICH HAVE NOT AS YET BEEN REPORTED FROM CHICHEN-ITZA.

This list, included for the sake of making complete the report on the birds obtained, contains merely notes on a few species obtained or observed in other parts of the peninsula, and not included in the foregoing list.

1. Tinamus robustus Sclater.

Tinamou.

A native proprietor of a chocolate shop in Progreso had a female bird of this species which was so tame that it went about under the tables picking up crumbs from the floor. It could usually be heard uttering a peculiar low whistle, which was capable, however, of being heard at a considerable distance. Two eggs laid by this bird, which I secured from the owner, are green-blue (robin's-egg blue) in color, and have a hard, glossy surface. They are spheroidal in shape and measure respectively 60.6 mm. × 47.3 mm., and 60 mm. ×

48.4 mm. The identification of this specimen is certain, as a description was made at the time, and feathers from various parts of the bird were brought home for comparison. Just where the bird came from is not so certain, but as nearly as I could learn, it came from somewhere in the interior of Yucatan. It is unfortunate that this could not be determined more definitely, as the species appears not to have been previously reported from the peninsula, though it is known to occur to the southward in Guatemala and Honduras.

2. Creciscus ruber (Sclater & Salvin).

One specimen: ♂, Yucatan (Xbac ?), 1901, G. F. Gaumer.

3. Larus philadelphia (Ord).

Bonaparte's Gull.

Large flocks on the Gulf at Progreso in the latter part of January.

4. Fregata aquila (Linné).

Man-o'-war Bird.

Common along the coast at Progreso during the latter part of January.

5. Speotyto cunicularia hypogaea (Bonaparte).

Burrowing Owl.

A single specimen, a female, was taken on the open ground of a henequen plantation at San Ignacio on February 9. Although well known from other parts of Mexico, this bird appears not to have been noted previously from Yucatan.

6. Ceryle alcyon (Linné).

Belted Kingfisher.

Common about the brackish Mangrove marshes back of Progreso during the latter part of January.

7. Momotus lessonii Lesson.

Lesson's Motmot.

One specimen, said to have been taken at Xbac in 1901, was given me by Dr. G. F. Gaumer.

8. Coccyzus minor (Gmelin).

Mangrove Cuckoo.

One specimen was given me by Dr. Gaumer.

9. Pyrocephalus rubineus mexicanus (Sclater).

Vermilion Flycatcher.

Two specimens were given me by Dr. Gaumer.

Rather common in the swampy land back of Progreso.

10. Heleodytes guttatus (Gould).

Yucatan Cactus Wren.

Three specimens:

a. ♀, Progreso, Feb. 4, 1904.

b, c. Xbac (?), 1901, G. F. Gaumer.

Although I obtained this bird at Progreso, whence it has been reported several times, I have no notes on its abundance or habits.

11. Mimus gilvus gracillis (Cabot).

Yucatan Mockingbird.

Maya neme, *tsī-kō*. "Native name 'Chico,' or 'Zenzotl.' The name of 'Zenzotl' is generally given in Mexico to all the species of Mocking-birds." — Boucard, Proc., Zool. Soc. Lond., 1883, p. 439.

One specimen, given me by Dr. Gaumer.

I found this bird common at Progreso, but did not see it at Chichen-Itza.

12. Cyanerpes cyaneus (Linné).

Blue Honey Creeper.

One specimen: Xbac (?), 1901, G. F. Gaumer.

Although reported from other States of Mexico and from other parts of Central America, there appears to be no previous record of this bird from Yucatan.

13. Volatinia jacarini splendens (Vieillot).

Blue-black Grassquit.

One specimen: [♂], Xbac (?), 1901, G. F. Gaumer.

REPTILIA, AMPHIBIA, AND PISCES.

By Thomas Barbour and Leon J. Cole.

Introduction.

The collections upon which this report is based are from the following sources: First, series obtained by Mr. Leon J. Cole; secondly, specimens from Mr. Edward H. Thompson, received at various times; thirdly, specimens in the Museum of Comparative Zoölogy from various sources other than those mentioned.

The literature on the lower vertebrates of Yucatan is not very extensive. Large collections have been made by Dr. G. F. Gaumer at various localities, and upon these specimens, for the most part, are based the Yucatan records of the Biologia Centrali-Americana. Ives, in the Proceedings of the Phila. Acad. for 1891, reported on the reptiles collected by Professor Heilprin's party; he described *Anolis acutirostris* as new; we record this species for the second time. Cope, in several papers, has also added

to our knowledge of the herpetology of Yucatan. Of the fishes less is known. The expedition of the *Albatross* to Cozumel Island resulted in a report on the fauna of that area; beyond this, however, little seems to have been published of the coast fishes. The fresh-water fishes are very few in number; that they are of great interest will be observed by examining the list which follows. Their distribution in the cenotes at Chichen-Itza is of especial interest. In the Sacred Cenote and in another cenote some three or four miles to the eastward and known as "Ikil" occur two entirely distinct species of catfishes, both of which, moreover, are new to science. Their habits are entirely distinct, as well as their specific morphological characters. This fact would appear to preclude the notion that these cenotes are connected by underground streams. On the other hand the "mojarra," *Heros urophthalmus*, occurs in both the Sacred and the great Cenote at Chichen-Itza, and is probably widely distributed throughout the peninsula. It is common in the brackish waters of the *cienaga* at Progreso. It has previously been reported only from Lake Peten, in Guatemala. This fish is used extensively for food and it is possible that the Indians have aided in its dissemination. One other species, *Heros affinis*, found in the *cienaga*, has been known previously only from Lake Peten.

Only a word is necessary to explain the apparent faunal relationships of the lower vertebrates of the Yucatan peninsula. Its fauna is, as would be expected, made up of typical species abundant in Mexico and in Central America. A few of the species are peculiar to the region. They, however, show no such special modifications as might have developed from peculiar local conditions, so that it seems reasonable to expect that with further investigation they may be found in the neighboring regions. In this way the lower vertebrates differ from the birds and mammals, which appear to have developed numerous local geographical races peculiar to Yucatan.

It is our pleasure to acknowledge our indebtedness to Dr. Leonhard Stejneger, Dr. B. W. Evermann, Mr. Samuel Garman, and Dr. Alex. G. Ruthven for advice and assistance in identification.

REPTILIA.

TESTUDINATA.

1. Cistudo mexicana (Gray).

Two examples from Chichen-Itza, Yucatan — an alcoholic specimen taken April 8, and a dried carapace.

2. Cinosternon leucostomum A. Dumeril.

One adult, dried, collected by Dr. G. F. Gaumer. Two young, in alcohol, from Chichen-Itza, taken by Mr. E. H. Thompson. Turtles, probably of this species, were reported several times as having been seen in the Sacred Cenote.

The specimens agree with the descriptions except that the first vertebral plate has convex sides instead of concave. The axillary and inguinal plates are in contact.

3. Thallasochelys cephalo (Schneider).

Skull found on the beach at Progreso. From the number of shells seen this species must be very common.

LACERTILIA.

4. Hemidactylus exsul, sp. nov.

Type. — No. 7039, Mus. Comp. Zoöl. Progreso, Yucatan, April 13, 1904. Leon J. Cole.

Snout about equal to distance between eye and ear openings: forehead concave: ear opening medium, ovoid, oblique. Body and limbs moderate. Digits rather dilated: two divided lamellae under the inner fingers; five under the second; six under the others. Three divided lamellae under the inner toes; six or seven under the others. Below these there are from one to three undivided lamellae beneath both fingers and toes. Granules on snout larger than those elsewhere. Among the granules of the back are fifteen rather irregular series of subtrihedral granules. These are about the same size as the ear opening, sometimes rather smaller. Rostral four-sided with a median cleft above, a little broader than high. Nostril between rostral, first labial, and three nasals. Mental large and subpentagonal: first pair of chin shields almost in contact behind the mental. Ventral scales small, subcycloid, slightly imbricate. Male with eight preanal pores in a curved series. Tail rather depressed, bearing tubercles on its base and rather large transverse plates below.

Color in alcohol: Grayish brown above, somewhat marbled with cinnamon, the darker spots occurring in three irregular series along the dorsal region and very irregularly on the head.

5. Thecadactylus rapicauda (Houttuyn).

One example from Chichen-Itza, Yucatan. Collected by Mr. E. H. Thompson.

6. Anolis aureolus Cope.

Six examples from Chichen-Itza. Identified by Dr. Stejneger.

7. Anolis ustus Cope.

Five examples from Chichen-Itza. Inclined to brownish below; one example shows a light vertebral stripe.

8. Anolis beckeri Boulenger.

One example from Chichen-Itza. Apparently typical, but in rather poor condition.

9. Anolis acutirostris Ives.

Two examples from Chichen-Itza.

10. Norops yucatanicus, sp. nov.

Types. — Three specimens, No. 7036, Mus. Comp. Zoöl. Chichen-Itza, Yucatan, Leon J. Cole.

Habit rather stout; head about once and a half as long as broad, a very little shorter than the tibia. Scales on head subequal and unicarinate. Occipital scale much smaller than ear opening; six labials to below the centre of the eye ; ear opening oval and vertical; about one half the diameter of the eye. Gular appendage moderate, gular scales large and strongly keeled. Enlarged dorsal scales in twelve or thirteen rows. Lateral scales small and keeled. The adpressed hind limb reaches slightly beyond the tip of the snout; digits slightly dilated. Tail just about as long as head and body; covered with equal sharply keeled scales.

Color : (alcoholic specimen) uniform fawn color. In one specimen there is a dark dorsal band. This band is wider than the region of enlarged scales, and is prolonged half-way down the sides in points. The central area of this band is lighter than the lateral.

Two specimens are adult and one is young.

11. Basiliscus vittatus Wiegmann.

Five young examples and one female with eggs taken April 6, all from Chichen-Itza. There are many specimens in the Museum (M. C. Z. No. 6268) taken by Edw. H. Thompson at Merida.

12. Laemanctus alticoronatus Cope.

One example from Chichen-Itza.

Scales in 55 rows ; Boulenger gives the rows of scales at from 45 to 51, and in *L. serratus* Cope from 57 to 61 rows. This specimen approaches *L. serratus* in the rather distinct vertebral serration. There are no white lines on the neck and thighs in this example ; neither do white spots characteristically situated appear. This specimen seems ideally intermediate between the two species, but with only one specimen definite conclusions are unreasonable.

A description of the colors of the specimen while alive is added from the field notes : — "Under parts light yellowish green with brown markings ; above this on sides a white stripe ; then a reticulated region of darker green, and above this again a yellowish green stripe. Back with alternate blotches of green and black. Head bright pea green. Colors gradually fade towards tail. which becomes grayish brown."

13. Ctenosaura acanthura (Shaw).

A single example from Progreso, as well as a large series from Chichen-Itza.

Following Günther (Biol. Cent.-Amer., Rept., 1890, p. 56) we have placed these examples under this species. Ives (Proc. Phil. Acad. Nat. Sci., 1891, p. 459) records Yucatan examples under the name *C. cycluroides* Harlan.

14. Ctenosaura (Cachryx) defensor (Cope).

One example from Chichen-Itza.

According to Boulenger (Proc. Zool. Soc. London, 1886, p. 241) Cope's genus Cachryx is untenable because it has been shown to intergrade with Ctenosaura. Still its characters would seem sufficiently definitive to warrant the subgeneric use of the name.

15. Sceloporus chrysostictus Cope.

Three examples from Chichen-Itza, four from Progreso, and one from San Ignacio, taken on Feb. 9.

16. Sceloporus serrifer Cope.

One example taken March 15, at Chichen-Itza.

17. Sceloporus variabilis Wiegmann.

Eighteen examples from Progreso.

18. Cnemidophorus sexlineatus (Linné).

Sixteen examples from Chichen-Itza, nine from Progreso.

The specimens show very marked variability in size, marking, and squamation. We have the typical form as well as examples agreeing with descriptions of the varieties *mexicanus*, *angusticeps*, and *costatus* which Boulenger recognizes. For several specimens we would need to describe new subspecies were we to admit any to be different from the *forma typica*. It must be said, however, that among the large number which we have both taken and seen in Florida, no such variability ever occurs.

OPHIDIA.

19. Glauconia albifrons (Wagler).

One example from Chichen-Itza, collected in the Maya ruins by Mr. E. H. Thompson.

A second example has also been received, taken by Mr. E. H. Thompson at the same locality, date uncertain, but between 1890 and 1900.

20. Typhlops microstomus Cope.

One example, also from the Maya ruins near Chichen-Itza.

21. Leptognathus sanniola (Cope).

Three examples from Chichen-Itza. Two of these were taken by L. J. Cole, and one by Mr. E. H. Thompson.

These specimens show several peculiar variations from Cope's description. One example has three praeoculars on one side and two on the other. Two specimens have undivided anal scales, while the third specimen is incomplete and lacks the anal scale. These also have both more ventrals and subcaudals than seems typical. Cope's description calls for 156 + 55; while in ours the counts run $\frac{15}{162 + 77}$, $\frac{15}{152 + 72}$, and $\frac{15}{158 + 73}$. It is possible that the tail of Cope's specimen was broken.

In *L. dimidiata*, while the anal is undivided, there are no praeoculars and the ventrals count 185 – 195, subcaudals 98 – 126.

22. Tropidodipsas sartorii (Cope).

One example from Chichen-Itza. Agrees with var. A. of Boulenger, Cat. Snakes British Museum, **2**, p. 297. Scales $\frac{17}{191 + 63}$; there is one more ventral than the maximum number cited by Boulenger.

23. Leptodeira yucatanensis (Cope).

One example taken at Chichen-Itza by Mr. E. H. Thompson.

The cross bands descend to the ventrals, the lateral spots are general, the lower surfaces immaculate. Sc. $\frac{21}{190 + 65}$.

The stomach of this specimen, about 20 inches long, contained an example of *Ctenosaura acanthura* about 7 inches long.

Another specimen has been received, taken also at Chichen-Itza by E. H. Thompson, 189–.

24. Himantodes gemmistratus Cope.

Dipsas gracillima Günther. Biol. Cent.-Amer., Rept., 1895, p. 177, pl. 56, fig. B.

One example from Progreso, Yucatan. Sc. $\frac{17}{225 - 153}$; forty-four dark brown markings on body; thirty-one on tail.

An example from Chichen-Itza taken by Mr. E. H. Thompson, 189–, has recently been received.

25. Thamnophis saurita proxima (Say).

Three examples from La Cienaga, Progreso. Taken by L. J. Cole. These were sent to Mr. Alex. G. Ruthven of Ann Arbor, Michigan, who has very kindly returned the following remarks: —

"The three specimens sent me . . . belong to the *saurita* group, of Garter Snakes, as is shown by the position of the lateral stripe on the 3d and 4th

rows of dorsal scales, and the very slender body and long tail. As is to be expected, these specimens are most closely related to the nearest geographical representative of the group (*proxima*), and differ from this form but little. The proportionate length of the tail falls well within the limits of variation in *proxima*, as do also the number of caudal plates. The number of dorsal rows of scales (19–17) is exactly the same as in *proxima* specimens. In one of the specimens there are 7 supralabials on one side, which may or may not indicate a tendency toward a reduction in this region, but the number of ventral plates (150 in the only specimen in which they can be counted) is decidedly less than is normal in *proxima*, which has a range of variation from about 164 to 174. Since but one specimen has been examined this small number might be considered abnormal were it not for the fact that Orizaba specimens and Cope's type of *rutiloris*, both of which belong to this group, also possess a smaller number of ventral plates than is normally the case in *proxima* specimens.

"The general type of color is the same as in *proxima*. The ground color above is dark greenish olive, the belly light bluish. The lateral stripes are narrow and are situated on the 3d and 4th rows of dorsal scales. The dorsal stripe is rather inconspicuous. The labials are uniformly white (possibly red in life). There are the usual light bars on the preoculars in front of the eye, and on the lower postoculars. There are no spots on the end of the gastrosteges, on the dorsal scales, or labials. Dorsal scales 19–17 in all specimens; supralabials 8; 8; R. 7, L. 8: infralabials 10; R. 10, L. 11; 10: oculars 1–3; L. 2–3, R. 1–3; 1–3: temporals 1–2 in all: urosteges 88; 91; 81: gastrosteges 150; ?; ?."

26. Coluber triaspis Cope.

One specimen, young, from Chichen-Itza.

Concerning this specimen, Dr. Stejneger very kindly writes under date of Oct. 9, 1905:

"The snake is *Coluber triaspis*. I have compared it with the types of *C. flavirufus*, *mutabilis*, and *triaspis*. It is not the first mentioned; it agrees exactly with the second, which is probably a synonym of the third. *C. triaspis* type seems to be an abnormal specimen with 3 loreals and 4 first temporals, otherwise = *mutabilis*."

27. Herpetodryas carinatus (Linné).

One specimen lately received from Mr. E. H. Thompson. Taken at Chichen-Itza, 189–.

This specimen is interesting in that the median five series of scales are keeled; the median three distinctly, the outer pair considerably less so.

28. Coronella micropholis (Cope).

One example, adult taken at Chichen-Itza on April 6, 1904, by L. J. Cole. This is a large example and represents var. B. of Boulenger's Cat. Snakes Brit. Mus., **2**, p. 203, 204. Sc. $\frac{21}{212 + 53}$.

A second example, young and imperfect, was found in the same locality on March 6. This represents var. E., Boulenger, *loc. cit.*, **3**, p. 405.

A third, also young, has been received from Mr. E. H. Thompson. Taken at the same locality, during the years 1890–1900.

29. Conophis lineatus concolor (Cope).

One example from Chichen-Itza, taken April 6. Sc. $\frac{19}{166 + 72}$; this specimen seems to fall under *C. lineatus* var. B., Boulenger, *loc. cit.*, 3, p. 122, 123.

30. Ficimia olivacea publia (Cope).

One example from Chichen-Itza.

Sc. $\frac{17}{145 + 37}$; there are twenty-six bars on the body and nine on the tail. The internasals are perfectly distinct.

31. Geophis multitorques yucatanicus, subsp. nov.

Type. — One specimen, No. 7037, Mus. Comp. Zoöl. Chichen-Itza, Yucatan, March 6, 1904, Leon J. Cole.

This form differs from *G. multitorques* (Cope) in having seven upper labials, two postoculars, a divided anal, and in being uniform plum-brown in color. Each scale has a darker dot at its apex. Sc. $\frac{17}{174 + 31}$.

32. Elaps fulvius (Linné).

Two examples from Chichen-Itza.

One example with sixteen black annuli on the body; anal divided, and sc. $\frac{15}{217 + 43}$.

The other example has only thirteen annuli of black on the body, the anal is entire, and sc. $\frac{15}{221 + 41}$.

These seem to fall under var. B., Boulenger, *loc. cit.*, **3**, p. 424.

33. Crotalus terrificus (Laurenti).

Three examples from Chichen-Itza ; one young, two half-grown.

These fall under var. B. of Boulenger, *loc. cit.*, **3**, p. 575. The stripes on the neck are well marked in all three examples.

AMPHIBIA.

1. Rana virescens areolata (Baird & Girard).

Two specimens taken from brackish water in La Cienaga near Progreso, Jan. 28–Feb. 10. Four from Chichen-Itza taken during March.

2. Bufo valliceps Wiegmann.

Four specimens from Chichen-Itza taken during April.

"This toad trills at a high pitch." Ives reports this toad from Yucatan (Proc. Phil. Ac. Nat. Sci., 1892, 1891, p. 461).

3. Bufo marinus (Linné).

Seven examples from Chichen-Itza, Yucatan.

Both *B. marinus* and *B. valliceps* were common in the cenotes, and were often found about watering troughs at the house as well. They were breeding in February, and on Feb. 19 eggs were observed, though it is uncertain to which species they belonged. By March 18 the tadpoles had reached a length of 2 cm. or so in the Sacred Cenote, and had become scattered about instead of swimming in dense schools as before. Mr. Thompson says that when the toads come to the cenotes to breed they plunge directly off from the top of the vertical walls to the water 65 feet below. The old toads after breeding and the young toads also appear to get out by working their way laboriously up the walls, taking advantage of the small irregularities.

4. Hyla phlebodes Stejneger.

Proc. U. S. Nat. Mus., 1906, **30**, pp. 817, 818.

Two examples from Chichen-Itza, compared with the type by Dr. Stejneger.

5. Hyla baudinii Dumeril & Bibron.

One example taken March 22, at Chichen-Itza, Yucatan.

"Call of this species a resonant *kwa, kwa, kwa* (*a* as in father). Most frequently heard in a tall cocoanut-palm. At night they come down to among the challote vines which grow about the water tank. The note is pitched low, but is of a far-reaching quality. Usually uttered three or four times in succession, at intervals of perhaps five minutes."

6. Triprion petasatus (Cope).

One specimen taken at Chichen-Itza, March 28.

"Note an unmusical, rather drawn-out *quarr — quarr — quarr*. Not guttural, but with a rasping quality. Life colors as follows: Top of head fuscous, with silvery greenish gray dots; back silvery gray, with dark fuscous blotches and smaller spots; sides with yellowish green suffusion; arms and legs brown, with yellowish blotches on upper arms and legs; silvery gray on lower arms and legs. Under sides whitish. The gray has a decided greenish tinge, which became more marked in a short time while the creature was held in the hand. This frog was not heard during the drier part of the season (February and most of March), but was heard quite frequently during the last part of March, when there was more rain."

7. Spelerpes yucatanus Peters.

S. yucatanicus Boulenger. Cat. Batr. Grad. Brit. Mus., 1862, p. 72.

One specimen from Chichen-Itza, taken, together with a single egg, in the damp earth near a watering trough on March 7.

PISCES.

1. Scoliodon terrae-novae (Richardson).

One specimen from Progreso.

2. Sphyrna tiburo (Linné).

One specimen from Progreso.

3. Urolophus jamaicensis (Cuvier).

One specimen from Progreso.

4. Dasybatis hastata (DeKay).

One specimen from Progreso.

This species seems to be considered a favorite food fish.

5. Felichthys marinus (Mitchill).

Two specimens from the Gulf of Mexico at Progreso.

6. Rhamdia depressa, sp. nov.

Plate 1.

Types. — Eleven examples, No. 29072, Mus. Comp. Zoöl. Ikil Cenote, near Chichen-Itza, Yucatan, Leon J. Cole.

Head $4\frac{3}{5}$; D. 1, 6 ; A. 10. Body rather slender, more stout anteriorly than posteriorly; head rather large, flat, narrowed forward. Eye rather high up, small, its diameter $6\frac{2}{3}$ in head. Teeth in bands. The maxillary barbel reaches the base of the anal fin; in some specimens it is rather shorter, but in none longer. The mental barbel reaches about half-way to base of pectoral, and the postmental considerably beyond the base of the pectoral fin. Origin of spinous dorsal fin rather less than half way from origin of ventral fins to gill opening. Length of base of adipose dorsal fin $3\frac{1}{2}$ in total length. The caudal fin is forked; its lobes are rounded but somewhat narrow. Ventral fins inserted below the posterior limit of the base of the spinous dorsal fin.

Color uniform dull brown. The largest specimen of this series is about a foot long.

Field notes. Ikil Cenote is about three miles east of Chichen-Itza. It is about 100 ft. in diameter, but on the east and south sides a projecting ledge covers it for nearly a third of the distance. A sounding through a well in this overhanging part gave 65 ft. to water, and 95 ft. depth of water. These silu-

roids were numerous and could be seen swimming slowly about near the surface. They took bait readily ; even if a stone was thrown in they swam rapidly to the spot.

7. Rhamdia sacrificii, sp. nov.

Plate 2.

Types. — Two examples, No. 29073, Mus. Comp. Zoöl. Sacrificial Cenote, near Chichen-Itza, Yucatan, Leon J. Cole.

Head $4\frac{3}{4}$; D. 1, 6; A. 10. Body stout its entire length; head large, flat, little narrowed forward. Eye very high up, small, its diameter $7\frac{1}{2}$ in head. Teeth in bands. The maxillary barbel reaches a little beyond the base of the ventral fins. The mental barbel reaches about three fifths of the distance to the pectoral, and the postmental a little beyond the base of the pectoral. Origin of spinous dorsal a little posterior to a vertical line from posterior part of base of pectoral fin. Length of base of adipose dorsal fin $2\frac{5}{6}$ in total length. The caudal fin is forked; its lobes are bluntly rounded, almost truncate. Ventral fins inserted a little caudad of the posterior limit of the spinous dorsal fin.

Color uniform dark slaty gray. The larger specimen is slightly more than one foot in length.

Unlike the preceding species, *R. sacrificii* appears to be a bottom form, and was never seen at the surface. It also took the bait much less readily.

8. Elops saurus Linné.

Two specimens from the Gulf of Mexico at Progreso.

9. Sardinella sardina (Poey).

Seventeen examples from the Gulf of Mexico at Progreso.

10. Stolephorus brownii (Gmelin).

Thirteen specimens from the Gulf of Mexico at Progreso.

11. Synodus foetens (Linné).

Two examples from the Gulf of Mexico.

12. Fundulus grandis Baird & Girard.

Eleven examples from La Cienaga near Progreso.

The largest size mentioned by Garman (Cyprinodonts, p. 97) for this species is six inches. Among this series, however, are several nearly ten inches long. The upper surface of the head is extremely flat: the eye, when seen in side view, has its upper edge elevated above the contour line of the head. It is rather more elevated than is shown in Girard's figure (Mex. Boundary Surv., **2**, p. 69, pl. 36).

13. Cyprinodon eximius Girard.

Fifty-one specimens from La Cienaga near Progreso, Yucatan.

14. Jordanella floridae Goode & Bean.

Twenty-five specimens from La Cienaga near Progreso.

15. Gambusia gracilis Heckel.

Eleven specimens from La Cienaga near Progreso.

16. Belonesox belizanus Kner.

Eight specimens from La Cienaga near Progreso.

17. Mollienisia latipinna Le Sueur.

Sixty-one examples (♂'s, ♀'s, and young) from La Cienaga near Progreso. Many examples have well-defined bands through the eyes passing upwards and forwards.

18. Tylosurus marinus (Walbaum).

Five examples from La Cienaga near Progreso.

19. Hyporhamphus unifasciatus (Ranzani).

Three specimens from the Gulf of Mexico near Progreso.

20. Mugil curema Cuvier & Valenciennes.

One specimen from the Gulf of Mexico near Progreso.

21. Mugil trichodon Poey.

One specimen from La Cienaga near Progreso.

22. Scomberomorus regalis (Bloch).

One specimen from the Gulf of Mexico at Progreso.

23. Caranx hippos (Linné).

One specimen from La Cienaga near Progreso.

24. Selene vomer (Linné).

One young specimen from the Gulf of Mexico at Progreso.

25. Epinephelus morio (Cuvier & Valenciennes).

Three specimens from the Gulf of Mexico at Progreso.

26 Diplectrum formosum (Linné).

Three specimens from the Gulf of Mexico at Progreso.

27. Neomaenis griseus (Linné).

One specimen from the Gulf of Mexico at Progreso.

28. Neomaenis synagris (Linnè).

Two specimens from the Gulf of Mexico at Progreso.

29. Haemulon plumieri (Lacépède).

Two specimens from the Gulf of Mexico at Progreso.

30. Orthopristis chrysopterus (Linné).

Five specimens from the Gulf of Mexico at Progreso.

31. Cynoscion nebulosus (Cuvier & Valenciennes).

One specimen from the Gulf of Mexico at Progreso.

"A much prized food fish."

32. Sagenichthys ancylodon (Bloch & Schneider).

One specimen from the Gulf of Mexico at Progreso.

33. Corvula sanctae luciae Jordan.

One specimen from La Cienaga near Progreso.

34. Bairdiella chrysura (Lacépède).

One specimen from the Gulf of Mexico at Progreso.

35. Menticirrhus americanus (Linné).

One specimen about one foot long, and five somewhat smaller from the Gulf of Mexico at Progreso.

36. Heros affinis Günther.

One specimen from Progreso, taken in La Cienaga.

This specimen does not agree exactly as to color markings and it has 15 dorsal spines instead of the usual 16. Previously known only from Lake Peten, Guatemala.

37. Heros urophthalmus Günther.

Many specimens from La Cienaga at Progreso and also from the Great and Sacred Cenotes at Chichen-Itza.

They range in size from one to about ten inches long. "At Progreso this fish is much used for food. It was common in the cenotes at Chichen-Itza, but the specimens taken did not appear to be as large as those taken near the coast. Their coloration was, however, somewhat brighter. Specimens from the Great Cenote have been introduced into the water troughs at the hacienda for three or four years. Here they were living very well. It was noted that

in the tanks containing these fishes mosquito larvae were entirely absent, whereas in the tanks without fishes larvae were exceedingly abundant. The fact that these fishes live so well in small bodies of water offers the suggestion that they may prove of practical value in aiding to subdue the mosquito pest in Yucatan."

This species has apparently been known thus far only from three specimens taken in Lake Peten by Salvin and Godman.

38. Balistes carolinensis Gmelin.

One specimen from the Gulf of Mexico at Progreso.

39. Lagocephalus pachycephalus (Ranzani).

Three specimens from the Gulf of Mexico at Progreso.

40. Lagocephalus laevigatus (Linné).

Two specimens from the Gulf of Mexico at Progreso.

41. Opsanus tau (Linné).

One specimen from Gulf of Mexico at Progreso.

42. Opsanus pardus (Goode & Bean).

Three specimens from Progreso, Gulf of Mexico.

43. Emblemaria atlantica Jordan & Evermann.

One specimen from La Cienaga near Progreso.

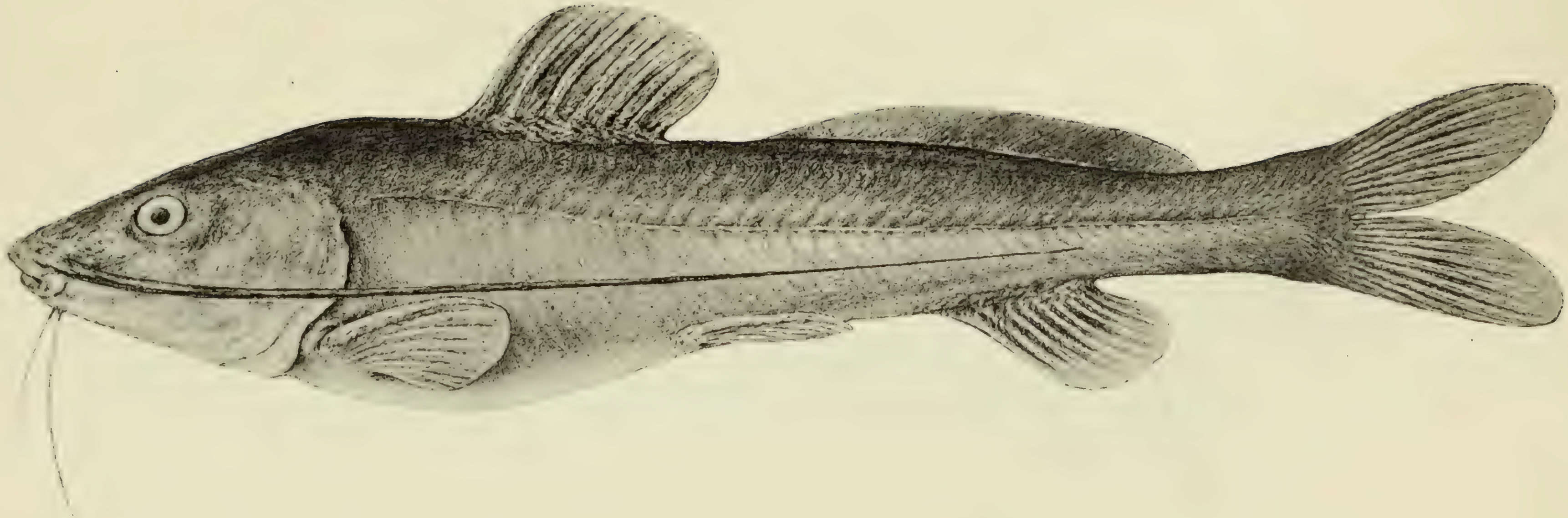
44. Echeneis naucrateoides Zuiew.

Two specimens from the Gulf of Mexico at Progreso.

One specimen with but 18 laminae in the disc, the other has 20. Jordan and Evermann (Fishes of North and Middle America, p. 2270) give 20 or 21 as the characteristic specific number.

45. Ogcocephalus vespertilio (Linné).

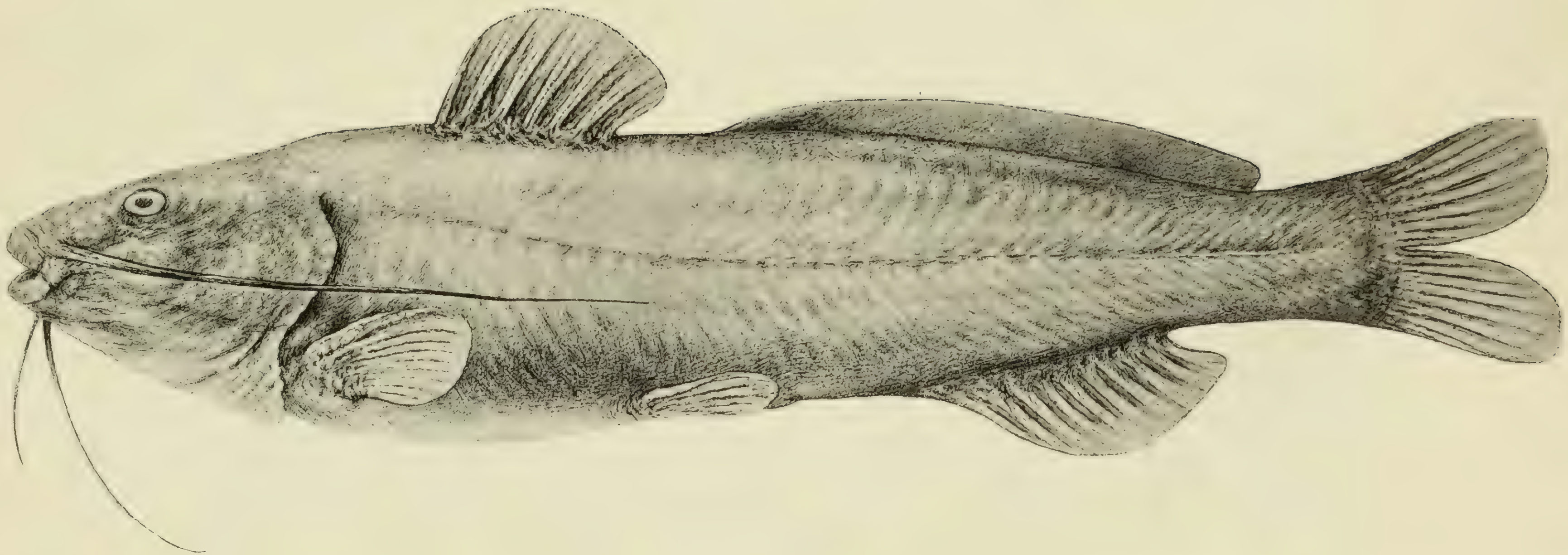
One young specimen from the Gulf of Mexico at Progreso.



C. H. L. GEBFERT, DEL.

HELIOTYPE CO., BOSTON.

RHAMDIA DEPRESSA.



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HELIOTYPE CO., BOSTON.

RHAMDIA SACRIFICII.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

VOL. L. NO. 6.

REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE EASTERN TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM OCTOBER, 1904, TO MARCH, 1905, LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

IX.

NEW SPECIES OF DINOFLAGELLATES.

BY CHARLES ATWOOD KOFOID.

WITH SEVENTEEN PLATES AND A CHART OF THE ROUTE.

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No. 6. — *Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of* ALEXANDER AGASSIZ, *by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905,* LIEUT. COMMANDER L. M. GARRETT, U. S. N., *commanding.*

IX.

NEW SPECIES OF DINOFLAGELLATES. BY CHARLES ATWOOD KOFOID.

THE pelagic collections of the Expedition made with the fine silk nets, especially those made at the depth of 300 fms. and brought to the surface in the open net, have contained a considerable number of species of Dinoflagellates which are as yet undescribed. Pending the publication of the final report with full illustrations, the following brief descriptions, accompanied by simple figures, are published of the new forms for which the plates are in preparation.

No attempt is made in these descriptions to discuss morphological or systematic problems, nor to indicate or discuss the distribution of the forms described. Nor is any list of the species found given herewith, since practically all known species of this group have occurred in the collections.

Noteworthy among the forms here described is the considerable number of new species of *Amphisolenia, Heterodinium, Ceratium,* and *Oxytoxum.* There is also included a new genus, *Acanthodinium,* which throws some light on the relationships of the problematical organism *Cladopyxis,* linking it with little doubt near to the Ceratiidae in the system. A unique new genus, *Centrodinium,* is represented by three species, and *Murrayella,* related to *Oxytoxum,* including four species, is also new. The plates of the obscure and puzzling genus *Protoceratium* are defined for the first time, and three species are added to the highly phosphorescent genus *Pyrocystis.* The discovery of a new representative of *Ptychodiscus,* a genus not reported since its description by Stein in 1883, is recorded.

In all three new genera, eighty-four new species, nine new "forms" are described. Unless otherwise stated they are all from collections

made by nets of No. 12 or 20 silk towed at depths of 300 fms., but open during both the descent and ascent. The types will be deposited in the United States National Museum, and co-types in the Museum of Comparative Zoölogy of Harvard College.

The species described are distributed as follows in the system: —

DINOFLAGELLIDIA.

ADINIDA.

Prorocentridae.

1. Prorocentrum curvatum.

DINIFERIDA.

Gymnodinina.

Pyrocystidae.

2. Pyrocystis acuta.
3. Pyrocystis fusiformis forma biconica.
4. Pyrocystis semicircularis (Schröder.)
5. Pyrocystis robusta.

Gymnodinidae.

6. Pouchetia panamensis.

Peridinina.

Ptychodiscidae.

7. Ptychodiscus carinatus.

Ceratiidae.

Ceratiinae.

8. Steiniella inflata.
9. Protoceratium areolatum.
10. Ceratium axiale.
11. Ceratium bigelowi.
12. Ceratium claviger.
13. Ceratium ehrenbergi.
14. Ceratium pacificum Schröeder.
15. Ceratium dilatata (Karsten).
16. Ceratium lanceolatum.
17. Ceratium pennatum.
18. Ceratium pennatum forma propria.
19. Ceratium pennatum f. inflata.
20. Ceratium pennatum f. falcata.
21. Ceratium schroeteri Schröder.
22. Ceratium scapiforme.
23. Ceratium tricarinatum.
24. Peridinium fatulipes.
25. Peridinium grande.
26. Peridinium latissimum.
27. Peridinium longispinum.
28. Peridinium murrayi.
29. Peridinium tenuissimum.
30. Heterodinium agassizi.
31. Heterodinium calvum.
32. Heterodinium curvatum.
33. Heterodinium expansum.

34. Heterodinium fenestratum.
35. Heterodinium fides.
36. Heterodinium gesticulatum.
37. Heterodinium gesticulatum forma typica.
38. Heterodinium gesticulatum f. extrema.
39. Heterodinium gesticulatum f. mediocris.
40. Heterodinium gesticulatum f. deformata.
41. Heterodinium globosum.
42. Heterodinium hindmarchi f. maculata.
43. Heterodinium laticinctum.
44. Heterodinium longum.
45. Heterodinium obesum.
46. Heterodinium praetextum.
47. Heterodinium superbum.
48. Centrodinium complanatum (Cleve).
49. Centrodinium deflexum.
50. Centrodinium elongatum.

PODOLAMPINAE.

51. Podolampas reticulata.

OXYTOXINAE.

52. Oxytoxum challengeroides.
53. Oxytoxum compressum.
54. Oxytoxum cristatum.
55. Oxytoxum curvicaudatum.
56. Oxytoxum gigas.
57. Oxytoxum subulatum.
58. Oxytoxum turbo.
59. Murrayella globosa.
60. Murrayella spinosa.
61. Murrayella punctata (Cleve).
62. Murrayella rotundata.

Cladopyxidae.

63. Acanthodinium caryophyllum.
64. Acanthodinium spinosum.

Dinophysidae.

65. Phalacroma lenticula.
66. Phalacroma reticulata.
67. Phalacroma striata.
68. Phalacroma ultima.
69. Dinophysis triacantha.
70. Amphisolenia asymmetrica.
71. Amphisolenia bispinosa.
72. Amphisolenia brevicauda.
73. Amphisolenia clavipes.
74. Amphisolenia curvata.
75. Amphisolenia dolichocephalica.
76. Amphisolenia extensa.
77. Amphisolenia laticincta.
78. Amphisolenia lemmermanni.
79. Amphisolenia palaeotheroides.
80. Amphisolenia projecta.
81. Amphisolenia quadrispina.
82. Amphisolenia quinquecauda.
83. Amphisolenia rectangulata.
84. Amphisolenia schroederi.
85. Triposolenia longicornis.
86. Triposolenia fatula.
87. Triposolenia ambulatrix.
88. Histioneis carinata.
89. Histioneis garretti.
90. Histioneis josephinae.
91. Histioneis longicollis.
92. Histioneis navicula.
93. Histioneis paulseni.
94. Histioneis pulchra.
95. Histioneis reticulata.
96. Ornithocercus carolinae.
97. Ornithocercus heteroporus.
98. Ornithocercus serratus.

Amphilothidae.

99. Amphilothus quincuncialis.

Prorocentrum curvatum, sp. nov.

Plate 1, Figs. 1, 2.

A small species with lanceolate curved body.

Body elongated, its length (dorso-ventral axis) 3 times the transdiameter and 5.5 times the antero-posterior one. Ventral end widest, truncate, bearing a short median flagellar collar which is anterior to the level of the suture. The body has nearly straight lateral margins for 0.5 of the length, then tapers to a blunt point. Seen from the side the body is curved posteriorly, the more distally, till the dorsal apex is almost at right angles to the ventral axis. The posterior valve is concave, and nearly flat, the anterior is convex both dorso-ventrally and transversely.

The thecal wall bears 6–7 longitudinal rows of close set pores on each valve.

Chromatophores small, irregular, dark yellow.

Length (dorso-ventral axis), 65 μ; transdiameter, 22 μ.

Station, 4720.

Pyrocystis acuta, sp. nov.

Plate 1, Fig. 4.

A large species with slender, straight, or slightly concave, cylindrical body swollen at the centre and abruptly pointed at the tips. The length is 13–21 times the diameter of the swollen midregion. The shaft beyond the midbody is 0.35–0.6 of the greatest diameter. The taper to the acute point is confined within one transdiameter of the end. The ends and the midbody differentiate the species clearly from *P. lanceolata*.

Length, 675–1400 μ; transdiameter, 45–95 μ.

Stations, 4728, 4732, 4740.

Pyrocystis fusiformis f. biconica, f. nov.

Plate 1, Fig. 3.

A small biconical form with broadly rounded apices and midregion. Apparently intermediate in form between *P. noctiluca* and *P. fusiformis* but not plainly intergrading with either. The length is 1.4–2.75 times the diameter. Differs from *P. fusiformis* in its relatively greater girth and in its straight rather than convex sides.

Length, 160–380 μ; transdiameter, 60–215 μ.

Stations, 4728, 4732, 4740.

Pyrocystis semicircularis (Schroeder).[1]

Plate 1, Fig. 6.

A medium-sized species with small ellipsoidal midbody and long slender cylindrical tapering incurved horns. Often yoked in pairs, as in *P. hamulus.*

[1] Schröder, B. Beiträge zur Kenntnis des Phytoplanktons warmer Meere. Viert. Nat. Ges. Zurich, **51**, p. 319–377, 1906. Received while this paper was in press.

Outline of the couplet and of long-horned single individuals nearly circular or elliptical. Midbody more convex on inner than on outer face of the arc, its length 1.7–2 times its transdiameter. The horns are tapering, sharp pointed, their distal ends sharply incurved, or with sigmoid flexure. Their length 4.5–10 transdiameters. The two horns are unequal in length, one being 1.1 times th^e length of the other. The long and the short horns are joined in the couplets.

Differs from *P. hamulus* in the larger size, less abrupt flexure of the arms, in the absence of the sharp double flexure at the midbody, and in the fact that the arms are more nearly equal in length.

Long axis of ellipse, of single or yoked individuals, 315–580 μ; transdiameter of midbody, 40–62 μ.

Stations, 4691, 4728, 4740.

Pyrocystis robusta, sp. nov.

Plate 1, Fig. 5.

A small species of robust habit, deeply crescentic. Differs from *P. lunula* in its greater curvature, stouter body, and absence of central expansion.

Body fusiform but bent into a deep crescent whose tips nearly meet or even overlap. The convex margin is circular in outline, and the gap between the tips is less than 0.25 of the circumference. The diameter of the spherical or oval area enclosed by the crescent is 0.5, rarely 0.3–0.4, of the diameter of the larger circle. Greatest width at the middle of the body, tapering gradually to the tips. Width, 0.14–0.22 of the axial length.

Diameter of outer circle, 77–215 μ ; width of body at middle, 26–90 μ.

Stations, 4728, 4740.

Pouchetia panamensis, sp. nov.

Plate 1, Fig. 7.

A minute species with symmetrical ellipsoidal body and minute lens and melanosome.

Body elongated, ellipsoidal, its length 1.5 times its transdiameter. Epicone about equal to hypocone. Apex broadly rounded, antapex also rounded, flattened ventrally. Girdle very oblique, transverse furrow very wide, 0.2 of a transdiameter in width, deeply impressed, forming a descending right spiral, displaced 6.5 times its width, and with an overhang of 0.25 of the circumference. Longitudinal furrow, 0.25 of the width of the transverse furrow extending from near the apex to the antapex, where it widens and spreads in two lateral bifurcations, twisted 0.30 of the circumference around the body. Transverse flagellum arises at anterior junction and longitudinal at posterior junction of furrows. Ellipsoidal nucleus in hypocone, stout crescentic melanosome with minute spheroidal lens.

Length, 34 μ; transdiameter, 21 μ.

Anchorage at Panama.

Ptychodiscus carinatus, sp. nov.

Plate 1, Figs. 8, 9.

A small disk-shaped species with concave anterior and posterior faces, wide furrow and ventro-posterior keel with the longitudinal furrow on its edge.

Body low, flat, disk-shaped, its length, including the keel, 0.33 of the transdiameter, which equals the dorso-ventral diameter. Excluding the keel the length is less than 0.25 of the diameter. The epitheca is a circular disk, notched ventrally, with concave anterior face, and broadly rounded edges which pass over into the large transverse furrow.

The hypotheca is also circular, disk-shaped, with somewhat concave posterior face. It is smaller than the epitheca, its diameter being about 0.9 of that of the epitheca. The hypotheca bears a thin ventral keel passing in a radial position from the centre of the posterior face to the flagellar pore. Its height is greatest about one third of the length from the centre, and is about 0.16 of the diameter. It bears the linear longitudinal furrow on its ventro-posterior edge.

The girdle is very wide with rounded edges, is deeper laterally than dorsally, is wider proximally than distally, so that a slight descending right spiral with little displacement is present. The longitudinal furrow lies in the ventral depression of the keel, is elliptical in outline on the epitheca, where it extends 0.6 of the distance to the centre.

Surface without sutures, pores, or reticulations. Figure sketched from life. Material in formalin is somewhat less depressed.

Length, 28 μ; transdiameter, 90 μ.

Station, 4722.

Steiniella inflata, sp. nov.

Plate 2, Fig. 15.

A large hyaline species with robust body and with anterior end of longitudinal furrow bifurcated, very narrow girdle, and broad intercalary bands along sutures.

The body irregular and asymmetrical, its length 1.1 times the dorso-ventral and 1.2 times the transdiameter, its epitheca conical, deflected to the left, and rotund ventrally, the right side more rotund than the left. Its altitude 0.6 of the transdiameter. Apical pore in right margin of longitudinal furrow which passes beyond the apex.

Hypotheca larger than epitheca, its total altitude 0.7 of the total length and 0.8 of the transdiameter. Antapex asymmetrical, broadly rounded, longer upon the left side, with broad ventral excavation.

Girdle narrow, ribbed, slightly impressed, with prominent margins, forming a descending right spiral with displacement five times its own width. Both proximal and distal ends curved posteriorly, the latter more than the former. Longitudinal furrow passing nearly one fourth of the distance beyond the apex

toward the girdle, bifurcated near the apical pore, passing posteriorly 0.6 of the distance to the antapex.

Sutures marked by broad structureless intercalary bands. Epitheca with 5 precingulars, and 1 apical which is deeply cleft by the longitudinal furrow but appears to lack the dorsal median suture necessary to complete the division into two plates. A minute accessory plate in the precingular series at the left of the longitudinal furrow. Hypotheca with 5 postcingulars, 1 antapical, and an accessory near the longitudinal furrow. The right ventral precingular and left ventral postcingular are small plates.

Plates reticulate with characteristic reticulations similar to those of *S. fragilis*, with quite regular arrangement in places. Scattered nodal pores in the mesh and eccentric pores in each reticulation.

Length, 165 μ; transdiameter, 115 μ.

Station, 4728.

PROTOCERATIUM (Bergh) Kofoid.

The thecal plates of this genus have not hitherto been determined, as the known species have lacked suture ridges and the density of the contents has interfered with the determination of the thecal structure. The following species has the plates clearly defined, and the definition of the genus may be accordingly emended.

Thecal wall definitely divided into plates, epitheca with one hexagonal apical plate and no apical pore, six nearly equal precingulars, the midventral one adjacent to, or containing the anterior end of the longitudinal furrow; hypotheca with six nearly equal postcingulars, the midventral one smaller and forming the posterior part of the longitudinal furrow plate, and one large antapical.

Protoceratium areolatum, sp. nov.

Plate 12, Fig. 71.

A minute species of ellipsoidal form. Thecal wall coarsely areolate, sutures marked by heavy ribs.

Body almost a perfect ellipsoid, the length 1.25 times the diameter *in* the furrow, and nearly equalling the diameter *on* the lists of the girdle. Epitheca less than the hypotheca by the width of the girdle, a low dome, abruptly flaring into the wide list, its altitude 0.33 of the diameter on the lists. Midventral plate slightly flattened, left side slightly wider than the right.

Hypotheca hemispherical, midventral plate somewhat excavated.

The girdle is wide, with wide, membranous, ribbed lists, furrow scarcely impressed, forming a descending right spiral with displacement equalling its width. Flagellar pore at proximal end of posterior list. Longitudinal furrow confined to girdle and hypotheca, running back to antapical plate on the ventral postcingular.

Plates normal, suture lines marked by ridges somewhat heavier than those

about the areoles. Suture lines with fins. Spines at the angles. Wall areolate with very large subequal polygons, 13–15 on the circumference at the girdle, 4–6 in each of the pre- and postcingular plates. No pores.

Length, 29 μ; diameter, 22 μ.

Station, 4699.

Ceratium axiale, sp. nov.

Plate 4, Fig. 26.

A medium-sized species of the *C. tripos* group, with apical horn bent to the right, narrowly rounded shoulders and antapicals flexed close to the midbody and subparallel to the apical distally.

The midbody is rotund. The postmargin is a slightly asymmetrical arc whose radius equals the transdiameter. The antapicals are thus bent anteriorly very close to the midbody. The right horn is nearer to the midbody than the left, and bends laterally with more or less concavity on the outer face. It is longer than the left antapical, which is convex laterally and more removed from both the midbody and the apical horn. The distance between the antapicals distally is usually less than a transdiameter, while at the level of the girdle it is 1.25–1.75 transdiameters. The right antapical is sometimes bent beyond the apical, crossing it dorsally.

Length, 175–285 μ; transdiameter, 45–60 μ; left antapical, 110–160 μ; right antapical, 115–200 μ.

Stations, 4638–4732.

Ceratium bigelowi, sp. nov.

Plate 3, Fig. 22.

An elongated species of the *C. furca* group, with inflated midbody, whose greatest transdiameter is over twice that at the girdle, long curved apical, and left antapical whose end is curved dorsally and to the left. Apical horn slightly curved to the left. The height of the midbody above the girdle to the base of the apical horn is about four transdiameters at the girdle. Antapex of left horn spinulate. Ventral plate small, oblique, ellipsoidal. Right antapical very short, its end scarcely a transdiameter from the girdle. The hypotheca is relatively small, and the inflated part of the epitheca is in the region of the base of the apical plates.

Length, 900–1030 μ; transdiameter at girdle, 40 μ; greatest transdiameter of epitheca, 80–100 μ.

Stations, 4728–4730.

Ceratium claviger, sp. nov.

Plate 4, Fig. 27.

A small species related to *C. ranipes* with rounded shoulders and club-shaped, rarely bifurcated ends of the antapicals which are subparallel to the apical.

Apical horn straight, midbody as in *C. ranipes*. Postindentation slight, if

any, shoulders broadly rounded, the major curvature within about one transdiameter from the sides of the midbody at the level of the girdle. Antapicals often flexed outwardly distally. Their antapices swollen to 0.2–0.5 transdiameters in width or partially bifurcate in two subequal lobes, crowded with chromatophores and amyloid bodies. Thecal surface rugose, shoulders spinulate, a hyaline fin usually present on the postmargin.

Length, 210–350 μ; distance between arms at girdle, 80-120 μ; transdiameter of midbody, 35–40 μ; length of antapicals, 115–260 μ.

Stations, 4594–4713.

Ceratium ehrenbergi, sp. nov.

Plate 2, Fig. 16.

A small species of the *C. lineatum* group with rotund midbody and short horns. Midbody with convex margins and very convex dorsal face, excavated ventrally. Girdle somewhat anteriorly placed, with prominent lists. Apical horn short. Antapicals short, pointed, slightly divergent. Surface with linear striae.

Length, 90–110 μ; transdiameter, 50 μ.

Stations, 4711, 4719.

Ceratium pacificum, Schroeder.

Plate 3, Fig. 21.

A very elongated linear species of the *C. furca* group without expansion of a midbody. Total length, 20–30 transdiameters at the girdle. Epitheca with straight margins tapering evenly from girdle to apical pore. Hypotheca long, nearly two transdiameters in axial altitude. Left horn linear, in length from girdle to apex about 0.3 of the total length. Right horn parallel to left, straight, tapering, scarcely four transdiameters from girdle to its antapex. Postmargin narrow, girdle narrow and with feeble lists, ventral plate elongated, narrow. Chromatophores irregular, dark yellowish brown in color. Varies greatly in length.

Length, 400–775 μ; transdiameter, 27–30 μ.

In Humboldt Current.

Ceratium dilatata (Karsten).

Plate 4, Fig. 25.

A small species resembling *C. platycorne*, but of smaller size, more arcuate postmargin, and more uniformly expanded blade-like antapicals.

The midbody is about the same size as in *C. platycorne*, and passes abruptly into the apical horn, rarely tapering into it as it frequently does in that species. The distinguishing features of the species are the antapicals, which continue from the symmetrically arcuate postmargin to the level of the base of the apical or beyond it, in a regular curve, to a position parallel to the apical or even incurved as in my figure. The ends of the antapicals are not continued in the

parallel direction any considerable distance, and are not so much incurved as they frequently are in *C. platycorne.* The antapicals are flattened, of uniform width, or expanded very slightly towards the antapex. The tips are rounded, squarish, or truncate, rarely asymmetrically pointed.

Length, 95–135 μ; greatest lateral extension, 65–90 μ.

Station, 4732.

Ceratium lanceolatum, sp. nov.

Plate 3, Fig. 17.

A small species related to *C. furca,* without differentiated apical horn.

The epitheca is not constricted to form an apical horn, but the midbody extends to the apical pore or nearly to it. The apical pore is oblique or strictly terminal. The sides of the epitheca are convex, or in some cases slightly concave distally on the left side, as in *C. scapiforme.*

The hypotheca is low, its axial altitude equalling or exceeding the transdiameter. Antapicals short, stout, and straight, the right about half the length of the left.

Length, 95–122 μ; transdiameter, 19–22 μ.

Stations, 4717–4719.

Ceratium pennatum, sp. nov.

Plate 2, Figs. 12, 13, 14.

An elongated species of the *C. furca* group with elongated left antapical curved to the left and dorsally. Long apical, which is straight or curved evenly and but slightly to the left. Short right antapical usually present. An exceedingly variable species.

The midbody is quite variable in form, scarcely swollen in some cases, and merging gradually into the stout apical horn (*propria,* forma nov., Plate **2**, Fig. 12) or more or less swollen, both hypotheca and epitheca being enlarged as they approach the girdle, and more or less sharply delimited from the horns in which they are continued (*inflata,* forma nov., Plate **2**, Fig. 13). The species also varies in the curvature of the left antapical. This is gradual and distributed throughout most of the length in many individuals. In others it is limited to a short abrupt curve at the antapex (*falcata,* forma nov., Plate **2**, Fig. 14). This form is, as a rule, about half the size of f. *propria,* and may prove to be a distinct species. The length of the right antapical is also subject to great variation, being usually fairly well developed, though rarely attaining to a length of 0.5 of a transdiameter.

The concave faces of the curved horns are often greatly thickened in both the apical and left antapical.

This species differs from *C. strictum* (Okamura and Nishikawa) in the curvature of its horns, and from *C. bigelowi,* sp. nov. in the fact that its greatest transdiameter is at the girdle or very close to it.

Length, 360–1225 μ; transdiameter, 25–50 μ.

At many stations between 4574–4684.

Ceratium schroeteri, Schroeder.

Plate 3, Figs. 18, 19.

A small species resembling *C. digitatum,* but with less lateral expansion of the epitheca and less curvature of the antapicals than is found in that species.

Elongated, transdiameter at girdle 0.15 of the total length. Epitheca broad, tapering a short distance from the apex to a short, scarcely delimited apical horn, slightly scoop-shaped and twisted to the left. Antapical horns unequal, the end of the right 1.5 and of the left 2.4 transdiameters from the girdle at the lateral margin. The right horn is straight and tapering; the left is strongly curved dorsally and to the left, and the wall of its concave face is strongly thickened. Thecal wall, of the left antapical especially, scabrous with small spinules at the pores. Chromatophores numerous, irregular.

Length, 335 μ; transdiameter at girdle, 50 μ.

Station, 4594.

Ceratium scapiforme, sp. nov.

Plate 3, Fig. 23.

A species of from small to medium size, of the *C. furca* group showing affinities to both *C. pennatum* and *C. schroeteri.* With long tapering blade-like epitheca not inflated beyond the transdiameter at the girdle, a short oblique scarcely differentiated apical horn, elongated left antapical, and submedian girdle.

The epitheca is 10–11 transdiameters in altitude and its wall is thickened in the region of curvature on the concave face. The apical pore is oblique, opening antero-dextrally. The hypotheca is short in altitude, scarcely more than a transdiameter to the middle of the postobliquity. The right antapical is short and straight, its antapex being about a transdiameter from the girdle. The left antapical is curved dorsally and to the left throughout its length, the curvature near its base being somewhat greater than it is distally. The concave faces of both apical and left antapical horns have thickened walls.

Length, 460–530 μ; transdiameter, 25 μ.

Stations, 4719, 4740.

Ceratium tricarinatum, sp. nov.

Plate 3, Fig. 20.

A medium-sized species of the *C. furca* group with affinities to *C. bigelowi, C. digitatum,* and possibly *C. geniculatum.* Distinguished by the inflation of the epitheca into a tricarinate expansion which in its greatest transdiameter equals or exceeds that at the girdle.

One of the carinae is middorsal, and the other two latero-ventral, with sutures of the apical plates at two of the angles. The third suture is midventral. The three faces of the midbody are concave, especially anteriorly. The expansion tapers more or less abruptly into the apical horn and bends somewhat to the left as it passes into the horn, which is straight but directed a little ventrally from the axis.

The hypotheca is very short, scarcely a transdiameter in axial length. The left antapical is long, nearly equalling the altitude of the epitheca in length. It is curved more or less evenly to the left and dorsally. The right antapical is short, straight, a little more than a transdiameter in length, subparallel to the left horn or divergent.

Length, 270–350 μ ; transdiameter at girdle, 35–40 μ.

Stations, 4709–4736.

Peridinium fatulipes, sp. nov.

Plate 5, Fig. 30.

A medium-sized species of the *P. divergens* group characterized by its widely divergent, heavily reticulate antapicals with wide postmargin. It differs from *P. elegans* in its more divergent, widely set antapicals, and from *P. grande* in these same particulars, and also in its smaller size and in the peculiar distribution of its minute pores.

The body is elongated, its length 1.6 times the transdiameter and 2.5 times the dorso-ventral. Epitheca equals the hypotheca, both ventrally excavated. The epitheca resembles that of *P. grande* in proportion, having deeply concave lateral faces and long attenute apical horn.

The hypotheca is contracted to 0.5 of the transdiameter, above the level of the base of the antapicals, which are slender, tapering, and widely divergent, their length 0.4 of a transdiameter, and the distance between their tips 0.8–0.9 of a transdiameter. The postindentation is 0.3 of a transdiameter in depth, forming a broad arc, notched by the longitudinal furrow, as seen ventrally.

The girdle is narrow, slightly impressed, with low membranous ribbed lists, with little displacement or forming a slight ascending right spiral. Longitudinal furrow with high lists not projecting posteriorly beyond the postmargin.

Plates normal, three in middorsal series. Sutures with very broad bands of intercalary striae. Plates centrally reticulate with minute subequal irregular polygons, with minute pores irregularly distributed, not centrally located in the polygons, and not in the mesh itself.

Length, 147 μ ; transdiameter, 100 μ.

Station, 4732.

Peridinium grande, sp. nov.

Plate 5, Fig. 28.

A very large species of the *P. divergens* group with wide flaring girdle and long horns.

Body elongated, length 1.2–1.4 times the transdiameter and 2–2.3 times the dorso-ventral. Epitheca equals the hypotheca, girdle section very broadly reniform. Epitheca a very low cone with very flaring base, and dorsally set tapering apical horn, its altitude 0.6 of its transdiameter. Sides deeply concave.

Hypotheca less abruptly contracted than the epitheca, its transdiameter at base of the horns 0.33–0.4 of that at the girdle. Its altitude is 0.66–0.75 of

its transdiameter. The antapicals are slightly unequal, divergent, conical, acute, their length 0.35–0.45 of the transdiameter. The distance between the antapices is 0.38–0.45 of the transdiameter and is 1.3–1.5 times the depth of the postindentation which is subacute with nearly straight sides.

The antapicals diverge less than in *P. fatulipes.*

The girdle is narrow, median, nearly horizontal, furrow ribbed, scarcely impressed, not displaced, with low membranous ribbed lists. Longitudinal furrow with high membranous lists projecting posteriorly beyond the postmargin.

Plates normal, 3 in median dorsal series. Thecal wall faintly and minutely reticulate with small subequal polygons with very minute centrally located pores.

Length, 185–245 μ; transdiameter, 150–195 μ.

Stations, 4732, 4740.

Peridinium latissimum, sp. nov.

Plate 5, Figs. 31, 32.

A small species with foreshortened, dorso-ventrally flattened body and widely separated very short or obsolete antapicals.

Body pentagonal in face view, anterior margins straight, postero-laterals convex, posterior concave. Its length, 0.8 of the transdiameter and 2.6 times the dorso-ventral. Epitheca, exceeding hypotheca, a low flattened cone, concave ventrally, convex dorsally, its altitude 0.4 of its transdiameter.

Hypotheca low, its altitude 0.45 of its transdiameter, equalling the distance between the low acute antapicals which in some individuals are almost obsolete.

Girdle narrow, almost horizontal, slightly postmedian, furrow deeply impressed, scarcely displaced.

Sutures marked by narrow bands, plates normal, 3 on dorsal side of epitheca. Surface minutely reticulate.

Length, 112 μ; transdiameter, 89 μ; dorso-ventral, 35 μ.

Stations, 4671, 4709.

Peridinium longispinum, sp. nov.

Plate 5, Fig. 33.

Syn. *P. michaelis* Ehrbg. in part, Stein ('83), Taf. IX, Figs. 9 and 11.

A small species of the *P. pellucidum* group with two intercalary middorsal plates, attenuate apical horn, and two long slender finned antapical spines.

Body elongated, flattened dorso-ventrally, its total length including spines 1.2–1.5 times the transdiameter. Epitheca exceeds the hypotheca, is compressed conical with concave lateral faces, and attentuate apical 0.15–0.4 of a transdiameter in length. The altitude is 0.6–0.8 of the transdiameter.

The hypotheca is low, subtruncate posteriorly, with slightly concave post-

margin. It is excavated ventrally, and its left lateral face is nearly straight while its right one is concave. Its altitude, excluding spines, is 1.2–1.35 transdiameters. Antapical horns are not developed, but from the postangles arise two subequal, solid, acicular, finned spines which are slightly divergent. Their length is 0.2–0.45 of a transdiameter.

The girdle is postmedian; the transverse furrow is not indented, and forms an ascending right spiral displaced distally less than its width. It has hyaline ribbed lists. The longitudinal furrow reaches the postmargin, is expanded distally, but its low lists do not as a rule project beyond the postmargin.

Sutures with striate intercalary bands, surface of plates sparingly porulate.

Length, 60–105 μ; transdiameter, 50–85 μ.

Stations, 4613, 4711.

Peridinium murrayi, sp. nov.

Plate 5, Fig. 29.

Syn. *P. divergens*, Ehrbg. in Murray and Whitting ('99), Pl. 29, Fig. 4.

A large species resembling *P. oceanicum*, but differing from it in the much lower epitheca with more concave sides, longer apical horn, and longer and more divergent antapical horns.

Body compressed dorso-ventrally, dorso-ventral diameter 0.65 of the transdiameter, and about equal to the length of the apical, or either of the antapicals. Distance between the tips of the antapicals equals or exceeds the transdiameter.

Girdle nearly median, furrow not impressed, with high membranous ribbed lists, forming a descending right spiral displaced twice its width. Longitudinal furrow with high lists which project beyond the postmargin.

Chromatophores radiating, linear.

Length, 250 μ; transdiameter, 135 μ.

Station, 4736.

Peridinium tenuissimum, sp. nov.

Plate 5, Fig. 34.

A minute hyaline species related to *P. pedunculatum*, but distinguished by its smaller size, more elongated body, and longer apical horn and antapical spines.

The length of the midbody excluding horn and spines exceeds the transdiameter. The midbody is broadly ovoid, passes abruptly into the cylindrical apical horn, whose length is but little less than a transdiameter. It flares slightly at the apical pore. The acicular divergent antapicals are nearly a transdiameter in length. The girdle is median on the midbody and is not displaced. The lists of the longitudinal furrow extend beyond the postmargin. The whole organism is exceedingly hyaline, plates and sutures not determinable.

Length, excluding antapical spines, 45–50 μ; transdiameter, 25–28 μ.

Station, 4711.

Heterodinium agassizi, sp. nov.

Plate 6, Fig. 35.

A small species with very broadly rounded apex, scoop-shaped epitheca, and subequal antapicals. The bifurcation is deep and evenly rounded. The reticulations are of medium size and fairly regular.

The epitheca is broad, its apex almost a semicircle, with a slight constriction some distance in front of the girdle but not so deep as in *H. fides.* Ventral surface concave. Altitude of epitheca on ventral face 1.16 times the transdiameter at the girdle, on the dorsal 0.82 times. Ventral area elongated, pit at its anterior end.

Hypotheca about equal to the epitheca. Its lateral margins nearly straight, convergent, distance between the tips of the antapicals a little less than 0.5 of a transdiameter. Postindentation deep, axial depth about 0.5 of a transdiameter, evenly rounded. Antapicals subequal, acute, scarcely spreading. Ventral face deeply impressed about the longitudinal furrow. Girdle narrow, oblique, displaced its own width, coarsely reticulate; not deeply impressed, ridges low.

Thecal wall reticulate with polygons of medium size, which are subregular along the margins. Reticulations porulate. Marginal sutures very heavy. Below the girdle on the dorsal side there are 34 contiguous reticulations and about 130 in the dorsal apical plate. Plates normal, obscure on ventral face of hypotheca.

Chromatophores bright cadmium yellow.

Length, 155 μ; transdiameter, 78 μ.

Station, 4699.

Heterodinium calvum, sp. nov.

Plate 7, Fig. 43.

A large spheroidal species with wide girdle and smooth wall.

Body spheroidal, flattened a little on the ventral face. Epitheca hemispheroidal, with rounded apex, flaring a little at the girdle. The ventral pit is median, in a quadrangular ventral area. The hypotheca is also hemispheroidal, with flattened antapex, with angular outline. It is excavated ventrally. The girdle is median, is very wide, especially in the distal half. The transverse furrow is impressed and the anterior ridge has considerable overhang. It forms a descending right spiral displaced its own width. The longitudinal furrow is slender, narrow, and extends but little beyond the posterior list of the distal end of the girdle.

The thecal wall is smooth, suture lines faintly marked, or with low ridges spinous in places, on the ventral face of the hypotheca. Porulate, but without other surface modification.

Length, 75 μ; transdiameter, 75 μ.

Station, 4739.

Heterodinium curvatum, sp. nov.

Plate 8, Fig. 48.

A large species with tapering epitheca deflected to the right, salient girdle, widely separated spreading antapicals with slightly incurved tips.

Body elongated, length nearly twice the transdiameter at the girdle, and nearly three times the greatest dorso-ventral extension. Epitheca contracted regularly from the base to the apical pore. Right margin somewhat concave, the left nearly straight, a feebly developed apical horn inclined to the right. Altitude about equals the transdiameter. Ventral area squarish, pit nearly central.

Hypotheca shorter than epitheca on ventral face, equal to it on the dorsal. Its altitude less than a transdiameter. More abruptly contracted than the epitheca to the base of the antapicals, which diverge but have incurved tips. Distance between the tips 0.6 of a transdiameter. Postindentation moderate, axial depth 0.4 of a transdiameter, the postmargin a very broad curve. Antapicals subequal, elongated, tapering, acute.

Girdle oblique, displaced its own width, obsolete distally, its posterior list decurrent on the right antapical. Furrow deeply impressed, with salient ridges partially reticulate.

Thecal plates normal ; sutures marked by smooth bands, or bands of minute polygons. Lateral sutures with high lists. Reticulations somewhat deficient on tips of apical and antapical horns and midcentral region of hypotheca. Reticulations relatively small, porulate, subequal, elongated and subregular along the lateral margins. About 150 reticulations on the dorsal apical plate and 34 contiguous to the girdle on the dorsal side.

Length, 235 μ ; transdiameter, 127 μ.

Station, 4699.

Heterodinium expansum, sp. nov.

Plate 6, Fig. 36.

A small species with short, stout, widely separated antapicals, nearly straight postmargin, and very oblique girdle.

The body is stout, its length being 1.3 transdiameters. It is strongly flattened dorso-ventrally, its greatest dorso-ventral extension being only 0.28 of a transdiameter. The girdle is very oblique, its antero-posterior extension being 0.3 of the total length. It is nearly median in position.

The epitheca is broadly rounded anteriorly in ventral view and passes abruptly into the short apical horn, which is deflected a little to the right and ventrally. Its altitude is 0.6 of a transdiameter and its ventral face flattened. The ventral area forms an elongated tract in the centre of the ventral face, and the ventral pit is located anteriorly in this area.

The hypotheca is convex laterally, excavated ventrally, with short, stout, acute, subequal antapical horns 0.18 of a transdiameter in length. The post-

margin is straight or nearly so, horizontal, and equals the axial altitude of the hypotheca in length.

The transverse furrow is not impressed, its posterior list is absent, and it forms a descending right spiral displaced distally its own width. The longitudinal furrow extends but half-way to the postmargin and is very narrow.

The left intercalary plate is large. Suture lines are marked by ridges. Thecal wall reticulate, with coarse, irregular, unequal polygons.

Length, 105 μ; transdiameter, 80 μ.

Station, 4637.

Heterodinium fenestratum, sp. nov.

Plate 8, Fig. 47.

A small species of robust habit, rotund body, short incurved antapicals, very coarse reticulations, and deficient posterior list to the girdle.

The body is very robust, the length being 1.36 times the transdiameter and 1.6 times the dorso-ventral diameter. The epitheca is abruptly contracted from the spreading girdle to a tapering apical horn which terminates in a large oblique or squarely truncate apical pore. Its altitude is 0.70–0.75 of a transdiameter. Its margins are in all views deeply concave. The ventral excavation is not marked. The ventral area is squarish with central pit.

The hypotheca is a little smaller than the epitheca, its altitude being about 0.45 of the total length. It is contracted less abruptly than the epitheca, having a width of 0.55 of a transdiameter at the level of the postindentation. The sides of the antapicals are nearly parallel to the main axis. The antapicals are short, stout, acute. The postindentation is very shallow, being 0.2–0.26 of a transdiameter in depth. The postmargin is a broad, quite regular curve.

The girdle is wide, is displaced 1.5–2 times its own width, slightly impressed, if at all, and bears a regular series of large reticulations. Its anterior ridge is heavy and ribbed, and the posterior one is obsolete or scarcely developed.

The plates are normal. The left intercalary is very small, embracing but one or two reticulations. The marked characteristic of the species is the very coarse reticulations each of which has 1–10 pores. There are 17 reticulations on the dorsal apical plate and 8 contiguous to the posterior margin of the girdle on the dorsal side. Suture lines are marked by very wide bands.

Length, 95–105 μ; transdiameter, 70–77 μ.

Stations, 4730, 4742.

Heterodinium fides, sp. nov.

Plate 7, Fig. 45.

A small species with constricted scoop-shaped epitheca, wide salient girdle, and short, divergent, subequal antapicals.

Body stout, its length 1.5 times the transdiameter and 2 times the greatest

dorso-ventral extension. Epitheca scoop-shaped, excavated ventrally, flaring at the girdle. Its altitude 0.75 of a transdiameter. Apex with broadly sloping slightly convex margins, which turn abruptly posteriorly to a broad, deep constriction just below the level of the ventral area, below which it abruptly expands to the girdle, thus giving to the epitheca a form which suggests the body of a violin. The ventral area is ellipsoidal, with the pit at its anterior end.

The hypotheca is somewhat shorter than the epitheca, its ventral altitude being less than 0.75 of a transdiameter. It is constricted somewhat rapidly, reaching 0.5 of a transdiameter at the level of the base of the antapicals. The antapicals are short, stout, acute, and divergent, their tips being less than 0.5 of a transdiameter apart. The postindentation is less than 0.25 of a transdiameter in depth and is broadly rounded.

The girdle is but slightly oblique, is displaced its own width, and is obsolete distally, its posterior ridge being decurrent on the right antapical. The furrow is deeply impressed, has very prominent ridges and coarse reticulations.

The thecal plates are normal. The left intercalary plate of the epitheca is unusually large. The reticulations are porulate, relatively large, and somewhat irregular.

Length, 123 μ; transdiameter, 83 μ.

Station, 4228.

Heterodinium gesticulatum, sp. nov.

Plate 6, Figs. 37, 38, 39, 40.

A medium-sized species with rounded apex, right antapical deflected strongly to the right and the posterior angle of the postcingular plates on the left margin of the hypotheca strongly protuberant.

Body moderately elongated, the length 1.6 to 2.3 times the transdiameter (measured on the anterior ridge of the girdle). The epitheca is shorter and distinctly wider than the hypotheca. Its apex is broadly rounded, almost semicircular in face view, but the ventral face is not deeply excavated or scoop-shaped. It is often wider anteriorly than it is at the girdle, and may have a slight constriction just anterior to the girdle. The ventral area is irregularly squarish with central pit.

The hypotheca is narrower than the epitheca, its transdiameter at the girdle being 0.9 to 0.75 of that of the epitheca. Its ventral surface is flattened, the dorsal one rotund. The posterior part of the hypotheca beyond the suture between the postcingular[1] and antapical plates is deflected to the right, in extreme cases as much as 40°. The right antapical is deflected more than the left, attaining even 45° to the main axis, while the left is only 5°-10° or subparallel to the axis. The right margin of the epitheca is deeply concave, while the left is carried out in a more or less prominent, often decurved angle at the point just anterior to the suture between the left postcingular and the left ant-

[1] These plates were called postmedians in my earlier paper (: 05), On Heterodinium, etc., Univ. of Calif. Pubs. Zoöl., 2, p. 345.

apical plates. This salient angle is the most striking feature of the species. The antapicals are short or more or less elongated, acute, and divergent. The postindentation is deep or shallow, being 0.2–0.8 of a transdiameter (of hypotheca) in depth. The postmargin forms a broadly rounded or subacute bay, with a hyaline irregularly toothed fin along most of the margin.

Girdle slightly oblique, displaced a little less than its width, obsolete distally. Anterior ridge very heavy, posterior one scarcely developed.

The plates are normal, the left intercalary being relatively large. The sutures are marked by prominent ridges, or by broad bands with or without fine reticulations. Thecal wall porulate, covered with reticulations of medium size. About 20 contiguous to the posterior side of the girdle on the dorsal side in the dorsal apical. Reticulation often lacking on some of the plates.

Chromatophores few, centrally located, spheroidal. Sometimes massed in chromospheres.

This is the most abundant species of the genus in tropical waters. It is exceedingly variable, but the diverse forms are so well connected by intermediates that they must be regarded as one species. The following forms may be recognized: —

Forma *typica* (Plate 6, Fig. 37). With little constriction of epitheca, moderate marginal projection of the left postcingulars and postindentation.

Forma *extrema* (Plate 6, Fig. 38). With constricted epitheca and relatively narrow hypotheca, excessive marginal projection and deep postindentation, and considerable obliquity of the hypotheca.

Forma *mediocris* (Plate 6, Fig. 39). With little deflection of hypotheca and antapicals, less inequality in transdiameters, slight marginal projection, and often with moderate subacute postindentation.

Forma *deformata* (Plate 6, Fig. 40). With right or left antapical undeveloped.

Length, 118 to 170 μ; transdiameter of epitheca, 67 to 100 μ; of hypotheca, 48 to 91 μ.

At various stations between 4594 and 4724.

This species (forma *extrema*) is figured in Capt. R. F. Scott's "Voyage of the Discovery," Vol. 2, on the plate facing p. 192 under the legend "Peridineans caught on the voyage out."

Heterodinium globosum, sp. nov.

Plate 8, Fig. 51.

A small species with rotund body, short apical horn, and small spine-like antapicals, deficient list, and sparse reticulations.

The body is spheroidal, the length (excluding apical and antapical horns) about equals the transverse and dorso-ventral diameter. The total length is 1.3 times the transdiameter and 1.5 times the dorso-ventral. The epitheca is dome-shaped, flaring at the girdle, and constricted apically to a short, stout horn

with oblique apical pore deflected to the right. The ventral area is poorly defined and the pit is located far anteriorly.

The hypotheca is low dome-shaped with two short, acute, unequal, widely separated divergent antapicals. The left is 2–3 times the length of the right, and the distance between their tips is 0.45 of a transdiameter. The postindentation is very shallow and the postmargin a broad, irregular curve.

The girdle is slightly oblique, is displaced less than its own width, lacks the posterior list entirely. The furrow is not impressed, and is marked by sparsely distributed reticulations.

The plates are normal. The left intercalary is of medium size. The wall is porulate in the central areas of the plates, which are imperfectly reticulate or bounded by ridges. The suture lines are bounded by broad, structureless bands.

Length, 117 μ; transdiameter, 82 μ.

Stations, 4691, 4692, 4699.

Heterodinium hindmarchi, forma maculata, f. nov.

Plate 7, Fig. 42.

Distinguished from the typical *H. hindmarchi* by the character of the reticulations. The form, proportions, and dimensions resemble those of the species named, but the reticulations are entirely different. In the type they are coarse and subregular. In f. *maculata* they are exceedingly diverse in size. Distally on the apical and antapicals, the minute reticulations predominate. In the pre- and postcingular plates they are predominately marginal in the plates or intercalated in more or less complete horizontal series. They are also found in isolated and irregular groupings. Possibly such differences here constitute a specific distinction.

Length, 140 μ; transdiameter, 80 μ.

Station, 4691.

Heterodinium laticinctum, sp. nov.

Plate 7, Fig. 46.

A moderately large species with very oblique, very wide girdle, broadly rounded apex, angular hypotheca, and incurved unequal antapicals.

The body is robust, ovate in ventral view, its length 1.4 times the transdiameter and 1.8 times the dorso-ventral. The apex is semicircular in outline.

The epitheca is low scoop-shaped with slight excavation, foreshortened dorsally so that the dorsal precingulars are scarcely as wide as the girdle. The apical pore is displaced to the right. The ventral area is displaced to the left, is subcircular with eccentric pit.

The hypotheca is a little longer than the epitheca. Its sides are slightly convex, and the antapicals are incurved and very acute. The left is twice the length of the right. They arise toward the ventral face and make a sharp offset dorsally to meet the postcingular suture.

The postindentation is shallow, about 0.25 transdiameter in depth, and the postmargin is squarish, with serrate fin.

The girdle is very oblique, displaced its own width, has low anterior and posterior lists, the latter decurrent on the left antapical. The furrow is slightly impressed and bears a few transverse ribs.

The plates are normal, the left intercalary being very small. The sutures are marked by ribs which locally bear hyaline serrated lists. Plates porulate. Reticulation lacking on specimen seen.

Length, 148 μ; transdiameter, 105 μ.

Station, 4724.

Heterodinium longum, sp. nov.

Plate 7, Fig. 44.

A medium-sized species resembling *H. rigdenae* but more elongated, with deeper postindentation and higher epitheca. It also resembles *H. hindmarchi*, but can be distinguished from it by its wider epitheca with straighter sides and the absence of convergence in the antapicals.

The body is elongated, its length 1.5 times its transdiameter, compressed dorso-ventrally. The epitheca exceeds the hypotheca, its length being about 0.6 of the total length. It is compressed conical, with straight margins and apical but little deflected to the right. The ventral area is squarish and deflected to the left with eccentric pit.

The hypotheca is contracted more than the epitheca, is convex anteriorly and concave posteriorly at the margins. The antapicals are pointed, stout, divergent, and subequal, the left often larger. The postindentation is deep, exceeding 0.5 of the altitude of the hypotheca. The postmargin is broadly rounded, and the tips 0.5 of a transdiameter apart.

The girdle is slightly oblique, displaced its own width, with slight anterior ridge and deficient posterior list obsolete distally. The furrow is not impressed and is more or less ribbed.

The plates are normal, suture lines well defined. Plates porulate, with coarse regular reticulations.

Length, 93–125 μ; transdiameter, 65–90 μ.

Stations, 4732, 4734, 4742.

Heterodinium obesum, sp. nov.

Plate 8, Fig. 50.

A minute species with spheroidal body, prominent apical horn, large hypotheca, and very unequal antapicals.

The body is robust; excluding all of the horns it is almost a sphere. The total length is 1.3 times the transverse or the dorso-ventral diameter. The epitheca is a low cone with slightly flaring base, nearly straight sides, and apex displaced ventrally. The total altitude is 0.6 of its transdiameter,

and the distance to the base of the horn 0.35 of the transdiameter. The apical pore is inclined a little to the right.

The ventral area is not strongly defined and the pit is not far removed from the girdle.

The hypotheca is very rotund, its greatest diameter being slightly below the girdle. Its total altitude is 0.8 of its transdiameter at the girdle, and its axial altitude 0.6. The left antapical is longer than the right and is formed by a blunt protuberant lobe whose width is half its height, bearing on its broadly rounded antapex a one or two-ribbed fin strongly deflected to the right. The right antapical is nothing but a finned spinule arising from the body, also deflected to the right.

The girdle is not oblique save in the distal third, where it is so deflected posteriorly that its displacement is twice its width. The anterior ridge is heavy, the posterior obsolete. The furrow is not impressed and is faintly ribbed.

The plates are normal, the left intercalary large, subtriangular. The suture lines are faint, marked by structureless bands. The plates are porulate with or without faint reticulations of relatively large size.

Length, 50 μ ; transdiameter, 37 μ.

Station, 4734.

Heterodinium praetextum, sp. nov.

Plate 7, Fig. 41.

A very large species of the subgenus *Euheterodinium* with slender, tapering, apical horn developed to a degree unusual in the genus.

The body is elongated, its length 1.3 times the transdiameter and 1.7 times the dorso-ventral. Epitheca exceeds the hypotheca in ventral view, and equals it dorsally. Its altitude is 0.8 of its transdiameter at the base, its ventral face is excavated, its laterals convex in the median region and concave distally, and the dorsal nearly straight. The apical horn is deflected to the right, and its length is 0.25 of the altitude. The midventral suture is strongly deflected to the left basally, and the ventral area is elongated, oblique, with eccentric pit.

The hypotheca is broadly excavated ventrally, abruptly contracted dorsally, and with feeble double curves laterally. The postindentation is shallow, forming an asymmetrical arc, its depth 0.3 of the altitude of the hypotheca. The antapicals are short, stout, bluntish.

The girdle is slightly oblique and postmedian, forming a descending right spiral displaced distally its own width. The furrow is scarcely impressed, with deflected posterior list obsolete distally and decurrent on left antapex.

The longitudinal furrow is short with low lists.

The thecal plates are normal, and the walls reticulate with subequal, subregular polygons which become smaller distally on the horns. The suture lines are marked by broad bands with imperfectly developed areas of minute reticulations.

Length, 240 μ; transdiameter, 180 μ.

Station, 4740.

Heterodinium superbum, sp. nov.

Plate 8, Fig. 49.

A very small species of robust habit, spheroidal body, and short spine-like antapicals. Reticulations rather coarse.

The body is elongated spheroidal, its length 1.28 times the transdiameter and 1.35 times the dorso-ventral diameter. The body is very rotund at the girdle. The epitheca and hypotheca are equal in length, but the latter is more rotund. The epitheca is subconical, its altitude is 0.56 of its transdiameter. It flares slightly at the girdle and its lateral margins have but little convexity. There is a partially developed apical horn, deflected to the right and set somewhat to the ventral side of the axis.

The hypotheca is very rotund, low dome-shaped, its altitude between the horns being a little less than 0.5 of its transdiameter. The antapicals are set to the ventral side in line with the apical, causing an abrupt shelf where the dorsal antapical plate joins the postcingulars. The right is 1.15 times the length of the left, which is 0.2 of a transdiameter in length. They are tapering, spine-like, with 0.3 of a transdiameter between tips. The postindentation is very shallow and the postmargin a broad curve.

The girdle is not oblique, is displaced its own width. The anterior list is very heavy, the posterior light and obsolete distally. The furrow is scarcely impressed and is heavily ribbed.

The plates are normal, the left intercalary triangular in form. The thecal wall is coarsely reticulate and porulate. There are about 30 reticulations in the dorsal apical and 15 contiguous to the girdle on the dorsal side. Suture lines with narrow ridges, minor reticulations or serrations.

Length, 74 μ; transdiameter, 59 μ.

Station, 4699.

CENTRODINIUM, gen. nov.

Steiniella (?) Cleve.

Ceratiinae with laterally compressed midbody contracted to an apical horn with pore and a single median antapical, median girdle on midbody, transverse furrow impressed, forming a descending right spiral. Longitudinal furrow mainly confined to hypotheca. Theca fully divided in discrete plates. Suture lines faint. Epitheca composed of apical and precingular series, 2 plates (possibly 4) in the former, and 6 in the latter. Girdle not distinctly divided into constituent plates. Hypotheca composed of 5 precingulars, 4 antapicals, and one dorsal intercalary. Thecal wall hyaline, structureless, porulate. Small ventral pore above the flagellar pore. Chromatophores present.

In warm temperate and tropical seas.

Centrodinium complanatum (Cleve).

Steiniella (?) *complanata,* Cleve.

Length 4–5 times dorso-ventral diameter. Midbody not abruptly set off from apical or antapical. Antapex not deflected to the left, bearing three short spinules. Apex and antapex coarsely porulate, the former not abruptly truncate.

Length, 300–400 μ ; dorso-ventral diameter, 75–80 μ.

Station, 4719.

Centrodinium deflexum, sp. nov.

Plate 9, Figs. 53, 54.

A medium-sized species with narrow apical, and antapical abruptly deflected to the left at an angle of 45°.

Body not greatly elongated, length 1.3 times the dorso-ventral diameter and 7 times the transdiameter. Epitheca and hypotheca nearly equal. Midbody laterally compressed, not flaring at the girdle laterally, dorsal and ventral margins both convex, epitheca abruptly contracted to the slender apical horn whose length is 0.5–0.12 of the transdiameter in length and broadly rounded at the end. This horn is directed obliquely dorsally in line with the trend of the ventral margin.

The hypotheca resembles the epitheca in proportions in lateral view, but the antapical horn is directed ventrally subparallel to the direction of the apical. In side view this is seen to be bent abruptly to the left as it leaves the midbody, at an angle of about 45°. The antapex bears 3 short spinules, 1 on the left and 2 on the right side.

Thecal wall hyaline, porulate, structureless, sutures faintly marked, apical and antapical regions coarsely porulate.

Length, 145–200 μ ; dorso-ventral diameter, 66–75 μ.

Stations, 4730, 4732.

Centrodinium elongatum, sp. nov.

Plate 9, Fig. 52.

A large species with truncate apex, epitheca shorter than hypotheca and long antapical horn.

Body elongated, length 3–4 times the dorso-ventral diameter and 7 times the transverse. Epitheca 0.3 of the total length, laterally compressed, flaring abruptly laterally to the girdle, ventral margin nearly straight, dorsal convex. Apical horn stout, short, abruptly truncate, its length equal to or exceeding its dorso-ventral width, and 0.35 of the dorso-ventral diameter in width.

Hypotheca greatly elongated, tapering within a transdiameter of the apex into the stout elongated antapical horn, its length 1.7–3 times its dorso-ventral diameter. Antapical horn cylindrical, curved to the left in a slight gradual curve, apparently twisted, terminating in three acute spinules.

Girdle narrow, median in the midbody, impressed, without salient ridges, forming a descending right spiral, displaced its own width. Longitudinal furrow extending a short distance on the epitheca where it contains an acccessory ventral pore and is continued posteriorly on the midbody as a diminishing groove nearly to the base of the antapical.

Thecal wall hyaline, finely porulate, larger pores on apex and antapex. Dorsal wall of apical greatly thickened.

Length, 275 μ; dorso-ventral diameter, 67 μ.

Station, 4722.

This is the type species of *Centrodinium*.

Podolampas reticulata, sp. nov.

Plate 2, Fig. 11.

A large species with the form of *P. biceps*, but with reticulate fins on the antapical spines. Their fins are very large and broadly rounded, with irregularly serrate margins and distal reticulations spreading from the spines. The fins are more decurrent laterally and less pointed than in *P. biceps*, and the spines 0.5–0.7 as long. The body is a trifle shorter and somewhat more rotund anteriorly and less squarish posteriorly.

Length of body, 80–92 μ; transdiameter, 70–75 μ.

Stations, 4638, 4732.

Oxytoxum challengeroides, sp. nov.

Plate 10, Fig. 65.

A medium-sized species resembling *O. milneri*, but shorter, with fine regular polygonal reticulations resembling those of the *Challengeridae*.

Body elongated, its length 3.7 times the transdiameter, which equals the dorso-ventral at the girdle. Epitheca 0.4 of the length of the hypotheca, low conical, flaring at the base, its altitude 1.17 times the transdiameter, tapering quickly into the short straight apical horn, which is displaced ventrally and has an asymmetrically pointed apex, the terminal spinule being on the left margin of the horn.

Hypotheca conical, with slightly convex sides, tapering without constriction into the pointed antapical, which is also somewhat displaced ventrally.

Girdle wide, 0.33 of the length from the apex, furrow deeply impressed, with well-defined margins, forming a descending right spiral displaced nearly its own width. Small accessory pore in its posterior margin in the midventral line behind the large flagellar pore. Longitudinal furrow not extended upon the hypotheca, with a tapering lanceolate extension 0.6 of the distance to the apex on the epitheca.

Plates normal, 5 apicals, pre- and postcingulars, one apical spine. Sutures with narrow bands, thecal wall minutely and subregularly reticulate with small hexagonal polygons, porulate.

Length, 80 μ; dorso-ventral diameter, 23 μ.

Station, 4732.

Oxytoxum compressum, sp. nov.

Plate 10, Fig. 63.

A medium-sized species resembling *O. cristatum*, but lacking the galeate apex, and having the antapical horn strongly deflected to the ventral side.

Body elongated, laterally compressed. Total length 2 times the transdiameter and 1.6 times the dorso-ventral. Epitheca 0.25 the total length, low campanulate or dome-shaped, flaring at the girdle, apex blunt, broadly rounded. Altitude of epitheca 0.5 of the transdiameter and 0.35 of the dorso-ventral diameter.

Hypotheca elongated, its length 1–1.4 times the dorso-ventral and 1.5 the transdiameter. Dorsal and ventral margins somewhat convex, gradually rounded posteriorly to the hook-like ventrally recurved antapical spine. Lateral margin but slightly convex, abruptly contracted to the antapical.

Girdle narrow, horizontal, ribbed, furrow deeply impressed with salient ridges, forming a descending right spiral displaced its own width, without overhang. Longitudinal furrow short, its length 0.3–0.4 of the total length, equally extended on both sides of girdle, both ends expanded.

Pre- and postcingular plates normal, apicals and antapicals not resolved into separate parts. Postcingulars with marginal and median striae, which are faintly outlined on epitheca also. Wall porulate.

Length, 100 μ; dorso-ventral diameter, 62 μ.

Stations, 4699, 4724.

Oxytoxum cristatum, sp. nov.

Plate 10, Fig. 64.

A medium-sized species with elongated laterally compressed body, galeate epitheca, and long antapical spine.

Total length 2.5 times the transverse and 1.85 times the dorso-ventral diameter. Epitheca 0.4 of the total length, helmet-shaped, with flaring base abruptly compressed laterally to a thin dorsally recurved apex. Apex a sharp horizontal, or even posteriorly deflected spine. Transverse diameter of the base 0.75 of the dorso-ventral and 0.9 of the altitude.

Hypotheca tapering obliquely to the ventral side, laterally compressed, lateral margins slightly convex, dorsal broadly rounded, ventral concave, abruptly contracted to a long, tapering, ventrally deflected, antapical spine, 0.4–0.6 of the transdiameter in length.

Girdle narrow, with salient margins, furrow impressed, forming a descending right spiral displaced its own width, no overhang, and with numerous stout ribs. Longitudinal furrow short, length 0.3 of the total length, nearly 0.6 of its course on the epitheca, elongated elliptical in form.

Neither apical nor antapical region resolvable into separate plates. Pre- and

postcingular plates, each with marginal and median rib, sometimes porulate, sometimes with very fine transverse tesselations.

Length, 100 μ; transdiameter, 38 μ; dorso-ventral, 50 μ.

Stations, 4730, 4732.

Oxytoxum curvicaudatum, sp. nov.

Plate 10, Fig. 61.

A minute species of robust habit. Body ellipsoidal, transverse and dorso-ventral diameter equal. Length 1.2 times the transdiameter. Altitude of epitheca scarcely 0.5 of the total length and 0.4 of its transdiameter, in the form of a low dome with blunt apex and convex sides.

Hypotheca over 2.5 times as high as the epitheca, the diameter of its base 1.25 times its altitude. Anteriorly the sides are slightly, if at all, convex. Antapex very broadly rounded, terminating in an acute, minute, antapical spur which is deflected ventrally to a horizontal position.

Girdle about 0.3 of the total length from the apex. Transverse furrow compressed, without lists or salient ridges forming a descending right spiral with displacement twice its width, with slight overhang.

Longitudinal furrow broad and shallow, its length 0.35 of the total length of the body, wider and longer on epitheca than on hypotheca.

Pre- and postcingular plates marked with eleven longitudinal striae, fainter upon the epitheca. Interstrial areas finely reticulated.

Girdle ribbed and areolated.

Length, 41 μ; diameter, 30 μ.

Station, 4711.

Oxytoxum gigas, sp. nov.

Plate 10, Fig. 59.

A very large species of slender habit, attentuate epitheca and hypotheca, galeate apex, and regularly tapering antapex, greatly displaced girdle, and minute pores in longitudinal striae.

The body is nearly biconical, the epitheca about 0.4 of the total length. Total length 4 times the dorso-ventral and 4.8 times the transdiameter. Epitheca subconical with concave sides, very little flare at the base, slight lateral compression, and somewhat elongated slightly galeate apex, broadly rounded and deflected dorsally. Its total altitude 2.2 times its transdiameter at the base.

Hypotheca a regularly tapering cone, slightly compressed laterally. Its total altitude 3.5 times its transdiameter at the base. Antapex not differentiated in form from the postcingular section, forming 0.22 of the total length of the hypotheca.

Girdle very narrow and very oblique ; furrow deep, with prominent but not salient margins, forming a descending right spiral displaced 7 times its own width, with numerous faint ribs and a few pores. Longitudinal furrow narrow,

of uniform width, its length 0.15 of the total length of the body. It extends from the proximal end of the transverse furrow posteriorly to a girdle width beyond its distal end. The flagellar pore lies near the proximal end.

Pre- and postcingular plates normal, sutures indistinct in apex and antapex, but each composed of several plates.

Thecal wall marked by equidistant striae containing regularly spaced pores. The striae along sutures somewhat heavier than the 2–3 intermediate ones on each plate. Striae are interrupted at the transverse sutures between the cingular and the terminal plates.

Length, 267 μ; transdiameter, 55 μ.

Station, 4732.

Probably *Steiniella mitra* Schütt[1] belongs in *Oxytoxum*.

Oxytoxum subulatum, sp. nov.

Plate 10, Fig. 62.

A large species of slender habit, elongated form, with abruptly contracted epitheca and long subulate apex.

The body is greatly elongated, its length 5–6 times the transdiameter and 4.5–5 times the dorso-ventral. There is little lateral compression. The epitheca is 0.9 of the length of the hypotheca. The epitheca is trumpet shaped with low abruptly contracted basal part and slender linear apical horn with sharp asymmetrical apex shaped like the point of a cannula with the excavation upon the right side, the relative length of the three parts, flaring base, horn and point, are respectively 0.18, 0.58, and 0.24 of the altitude of the epitheca, which is 2.3 times its transdiameter. The horn is set somewhat to the ventral side of the epitheca.

The hypotheca is almost conical, slightly gibbous just below the girdle, more on the ventral than on the dorsal side, contracted as it passes into the slender attenuate antapex. Its altitude is 2.8–3.2 times its transdiameter at the girdle. The antapical horn is slender, straight, its length a little less than 0.5 transdiameters.

The girdle is nearly horizontal, the furrow very deeply impressed with thin, slightly salient ridges, forming a descending right spiral displaced 0.5 of its width.

Apical region formed of 4 slender plates, antapical fused. Thecal wall with 10–12 longitudinal striae. Surface with minute areoles.

Length, 124–142 μ; transdiameter, 21–27 μ.

Stations, 4698, 4699.

Oxytoxum turbo, sp. nov.

Plate 10, Fig. 60.

A minute elongated top-shaped species with capitate epitheca.

Body elongated, its length 2.3 times the greatest transverse diameter, which

[1] Schütt, F. Die Peridineen der Plankton Expedition. Taf. 7, Fig. 27, 1895.

equals the dorso-ventral. The greatest diameter is a short distance posterior to the girdle. The epitheca is a small hemisphere with a short, stout, apical horn with blunt apex. The apical horn emerges very abruptly from the dome of the epitheca. The altitude of the epitheca above the girdle is 0.5 of its transdiameter, which in turn is 0.5 of the greatest transdiameter of the hypotheca, and about 0.16 of the total length.

The hypotheca is top-shaped, abruptly rounded to the girdle, tapering regularly posteriorly to an acute point.

The girdle is peculiar, very wide, its width 0.12 of the total length, and slightly exceeding the altitude of the epitheca. It is constricted to an acute-angled furrow at its middle, and extends anteriorly on the capitate epitheca and posteriorly upon the expanding hypotheca. Its margins are marked by faint lines with a prominent line of pores, especially in the hypotheca, where a low hyaline list also occurs. The list on the hypotheca is very low.

Plates normal, scarcely defined on epitheca, apical horn not separable, antapical also apparently fused. The surface faintly marked with punctate longitudinal striae.

Length, 50 μ; transdiameter, 22 μ.

Station, 4734.

MURRAYELLA, gen. nov.

Oxytoxinae with spheroidal body and medium girdle, epitheca and hypotheca nearly equal. Transverse furrow impressed, forming a descending right spiral with more or less displacement. Longitudinal furrow on both epitheca and hypotheca but not reaching the apex or antapex. Theca composed of discrete plates. Epitheca with 6 precingulars and 2–4 apicals and a small midventral intercalary next to the longitudinal furrow. No apical pore. Hypotheca composed of 5 postcingulars one of which is the longitudinal furrow plate, and an antapical apparently of one spine-like plate. Plates ribbed and reticulate. Chromatophores yellowish.

Ceratium biconicum Murr. et Whitt. and *Steiniella* (?) *punctata* Cleve belong in this genus.

Murrayella globosa, sp. nov.

Plate 9, Fig. 56.

A small globose species with epitheca equalling the hypotheca. Epitheca conical, its altitude 0.6 of a transdiameter. Apex rounded or with small acute point. Hypotheca hemispherical with short acute terminal spine deflected to the right. Left side somewhat more convex than the right. Girdle median, displaced distally its own width. Furrow deeply impressed, without lists or salient ridge, sparingly ribbed. Longitudinal furrow greatly widened on the epitheca, reaching 0.4 of the diameter to the apex and its width nearly equalling its height. Posteriorly the longitudinal furrow is narrow and not so expanded at the end as on the epitheca.

The sutures are marked by ridges with cross striae or by broad intercalary bands. The longitudinal furrow plate of the hypotheca is long and narrow. The postcingulars have a median rib. The surface of the plates is minutely and regularly reticulate. No pores.

Chromatophores small, spheroidal. Large central yellowish chromosphere.

Length, 68 μ; transdiameter, 59 μ.

Station, 4732.

This is the type of *Murrayella*.

Murrayella spinosa, sp. nov.

Plate 9, Fig. 57.

A small species of biconical form with antapical spine resembling *Amphidoma*.

Body biconical, epitheca longer than hypotheca, total length 1.4 times the transdiameter. Epitheca conical, its altitude 0.5 of its transdiameter, sides slightly convex. Antapex with short spine with a transverse fin.

Girdle postmedian, 0.55 of the length from the apex, impressed, without salient ridges, forming a descending right spiral displaced less than 0.5 of its own width, most of the displacement occurring in the *proximal* part of the furrow. Longitudinal furrow on the epitheca only a narrow groove terminating in a pit, on hypotheca two girdle widths in length with marginal lists.

Plates normal. Suture lines with broad reticulated bands and central seam. Plates finely reticulate with irregular polygons. Four apical plates. A mid-ventral accessory strip in the precingular row.

Length, 45 μ; transdiameter, 32 μ.

Station, 4732.

Murrayella punctata (Cleve).

Steiniella (?) *punctata* Cleve.

Plate 9, Fig. 58.

A small species, variable in size and proportions, biconical in form with median girdle and axis shifted ventrally.

Body elongated, length 1.55 times the dorso-ventral and 1.7 times the transdiameter. Epitheca and hypotheca subequal. Epitheca conical, its altitude 1.8 of its transdiameter, right and left margins straight or concave, base occasionally somewhat flaring, dorsal margin convex, more so than the ventral, apex displaced ventrally, broadly rounded.

Hypotheca resembling the epitheca, but its ventral face is concave, and the ventrally displaced antapex is more or less acute.

Girdle relatively wide in small individuals, and narrower in large ones, furrow deeply impressed with slightly salient margins, forming a descending right spiral displaced its own width. The longitudinal furrow is very long, 0.75 of the total length of the body. It runs from the girdle to the apex, narrowing gradually till at a point half-way to the apex it is continued as a linear channel. Near the middle of the epitheca it is deflected to the right. On the

hypotheca it turns to the right distally and forms a broad channel with high membranous lists on either side.

The post- and precingular plates are normal. There are four apicals and two antapicals. Suture lines are marked by bands, and the plates are finely reticulate with small subequal irregular polygons. The transverse and longitudinal furrows are partially reticulated. An exceedingly variable species.

Length, 65–155 μ; dorso-ventral diameter, 40–73 μ.

Stations, 4691, 4730, 4732.

Murrayella rotundata, sp. nov.

Plate 9, Fig. 55.

A minute spheroidal species without apical or antapical horns.

Body rotund, spheroidal, its length 1.05 times the dorso-ventral diameter. Epitheca less than the hypotheca, its altitude 0.42 of the total length and 0.44 of the dorso-ventral diameter, low dome-shaped, slightly flaring at girdle.

The hypotheca is symmetrical, less rotund than the epitheca, and less flaring at the girdle, almost hemispherical, with a minute antapical elevation a little to the ventral side of the antapical pole.

Girdle horizontal, slightly impressed, with salient ridges, forming a descending right spiral displaced its own width. Longitudinal furrow narrower than the girdle, extending one girdle width on the hypotheca and two on the epitheca.

Length, 45 μ ; dorso-ventral diameter, 43 μ.

Station, 4701.

ACANTHODINIUM, gen. nov.

(?) *Cladopyxis* Stein ('83) in part.

Body spheroidal with premedian girdle. Epitheca with apical pore, four apical and eight precingular plates. Hypotheca with two antapical, six postcingular plates, and a longitudinal furrow plate of two moieties. The pre- and postcingular plates and the antapicals usually bear a centrally located spine, which is simple or branched distally. Thecal wall porulate.

Acanthodinium caryophyllum, sp. nov.

Plate 11, Fig. 67.

Similar to *A. spinosum*, but with ends of spines quadripartite with hyaline films connecting the divisions. Spines with one axial pore canal, occasionally with two or three connecting or independent ones at the base. This axial canal branches peripherally in the processes, which are usually four, occasionally two or three. The thecal plates are similar in number and general arrangement to those of *A. spinosum*, and the spines show a similar distribution on the plates and are subject to similar irregularities in distribution. The spines are longer (0.7–0.9 transdiameters at girdle) than in *A. spinosum*, but in other respects the dimensions are nearly the same.

Possibly an older form of *A. spinosum.* Intermediate stages not, however, observed. Transdiameter of midbody, 40 μ; length of spines, 35 μ.

Station, 4722.

Acanthodinium spinosum, sp. nov.

Plate 11, Fig. 66.

Axial length of body (without spines) 1.1–1.2 transdiameters of girdle. Dorso-ventral and transverse diameters equal. Epitheca less than hypotheca. Altitude of epitheca 0.3–0.4 of the axial length from the apex. Transverse furrow very lightly indented, its proximal and distal ends not displaced. Longitudinal furrow short with low lists. Epitheca with small circular area about apical pore. Apical plates without spines. Dorsal and ventral apicals narrow, laterals very wide. Of the eight precingular plates the two midventrals are small, and the remaining six are large, subequal, and bear centrally located spines. The two laterals are often without spines.

In the hypotheca the plates are less regular. The two antapicals are unequal in size and may bear spines. The six postcingulars are also unequal, the left midventral being smaller and the others increasing in size to the right. The longitudinal furrow plate consists of a larger posterior and smaller anterior moiety. Spines have been found on all plates of the hypotheca excepting only the furrow plates and the left midventral postcingular. Spines 0.4–0.6 transdiameters at girdle in length, slightly curved conical, tapering evenly, to a sharp point, with one central pore canal. Suture lines marked by single, rarely doubled, ridges. Thecal wall porulate. Plates usually bordered by a peripheral pore-free band.

Length, 45 μ; diameter at girdle, 40 μ; length of spines 16–25 μ.

Stations, 4707, 4722.

This is the type of *Acanthodinium.*

Phalacroma lenticula, sp. nov.

Plate 12, Fig. 69.

A medium-sized species with lenticular body, very high epitheca, and finely reticulate wall.

Body lens-shaped, much compressed laterally, its transdiameter less than 0.25 of the dorso-ventral, nearly circular in lateral view, the dorso-ventral width of the body exclusive of the fin, 1.06 times the length, the longest antero-posterior axis being slightly oblique (10° antero-dorsally) to the girdle. The epitheca is unusually high, nearly equalling the hypotheca in length. The girdle is narrow, furrow not impressed, with low fins. Left ventral fin with two ribs, the right low, reticulate at the base.

Thecal wall finely reticulate, about 16 mesh on the radius at the girdle, minutely porulate.

Length, 81 μ; dorso-ventral diameter, 86 μ.

Station, 4749.

Phalacroma reticulata, sp. nov.

Plate 12, Fig. 72.

A small species of biconical form, laterally compressed, with very coarse reticulations.

The length is 1.6 times the transdiameter, and 1.25 times the dorso-ventral. The epitheca is a low symmetrical cone, laterally compressed, its altitude 0.48 of its dorso-ventral diameter and 0.57 of its transdiameter. Its sides are straight and the apex is broadly rounded.

The hypotheca is a high cone, its altitude a trifle less than its transdiameter and 0.8 of its dorso-ventral. Its ventral margin is convex in the middle, the dorsal nearly straight and the laterals a little concave. The antapex is rounded.

The girdle is 0.4 of the length from the apex and has low hyaline lists. The left ventral list is high, with a single prominent rib and several secondary ones. It is decurrent posteriorly and is continued around the hypotheca on the right side of the suture to the dorsal girdle, as a low list.

The surface is coarsely reticulate, with 24 polygons on the epithecal valve and 36 on the hypothecal.

Length, 100 μ; transdiameter, 64 μ.

Station, 4740.

Phalacroma striata, sp. nov.

Plate 12, Fig. 73.

A large species resembling *P. cuneus*, but differing in the form of antapex. In *P. cuneus* this is symmetrically contracted to a rounded antapex. In *P. striata* the hypotheca is relatively larger, is broadly rounded at the antapex and more expanded ventrally. The ventral margin is nearly straight, and forms a right angle with the girdle. The left ventral fin follows the outline of the body or even exaggerates the ventral expansion, and reaches the level of the antapex. It is faintly radially striate. Girdle with wide membranous lists.

Thecal wall reticulate, with coarse polygons each with central pore.

Length, 120 μ; dorso-ventral diameter in girdle, 120 μ.

Stations, 4638, 4719.

Phalacroma ultima, sp. nov.

Plate 12, Fig. 68.

A bizarre species of small size with bifurcated antapex and longitudinal furrow displaced to the right.

The length of the body is 1.6 times the greatest dorso-ventral extension, and 4 times the transdiameter (excluding the collars). The epitheca is low, its greatest altitude above the furrow is 0.35 of its dorso-ventral diameter. It is highest in the ventral third and declines rapidly dorsally.

The hypotheca is deeply and broadly bifurcated by a wide arc which reaches the posterior end of the longitudinal furrow. The depth of the bifurcation is but little less than the dorso-ventral diameter of the body in the girdle. As a result of the bifurcation there are two slender tapering acute horns, a shorter ventral and longer dorsal. Their length is about 0.75 of the distance between their tips.

The girdle is wide, with flaring sub-horizontal lists. The longitudinal furrow is turned abruptly to the right and runs on the right face of the organism to the dorsal side of base of the ventral horn. The suture between the valves follows this course and then turns abruptly toward the ventral margin of the horn.

There is a low ridge on the right side of the furrow which continues as a short spine beyond the posterior margin of the body.

Length, 60 μ; dorso-ventral diameter, 38 μ.

Station, 4711.

Dinophysis triacantha, sp. nov.

Plate 12, Fig. 74.

Related to *D. schütti* Murr. et Whitt. and *D. uracantha* Stein. Resembles *D. uracantha* in having marginal ribs to the postero-dorsal spine. Differs from both of these species in the presence of a third spine in the ventral fin, located at its dorso-posterior margin and formed as in the case of the postero-dorsal spine by marginal thickenings.

Body broadly ovate in lateral view, anterior collar unevenly ribbed, ventral fin feebly reticulated. Thecal wall with fine irregular reticulations, a few of which contain pores. The three spines subequal, in length about 0.5 of the dorso-ventral diameter of the body.

Length of body without spines or collar, 50 μ; greatest dorso-ventral diameter, 50 μ; spines, 20–25 μ.

Station, 4722.

Amphisolenia asymmetrica, sp. nov.

Plate 13, Fig. 76.

An elongated species resembling *A. dolichocephalica.* Total length nearly twenty-five times that of the neck and nearly fifty times the dorso-ventral diameter of the midbody. Head long, narrow, oblique, its long axis slightly exceeding the neck in length, with low spreading sparingly ribbed lists. Antapical stem curved ventrally and distally deflected abruptly to the right, bearing a short spine in the left face at the point of deflection and three equidistant terminal spinules on the slightly swollen end. Walls thickened distally along sutures which do not follow the median plane of symmetry through the apparently twisted antapex but divide it into two asymmetrical valves, the right with two terminal spinules and the left with one terminal and the lateral.

Nucleus elongated, chromatophores few, large, ellipsoidal.

Length, 1200 μ; dorso-ventral diameter of the midbody 60 μ; length of head, 190 μ.

Station, 4732.

Amphisolenia bispinosa, sp. nov.

Plate 14, Fig. 85.

A moderately large species of robust proportions, midbody but little expanded and tapering very gradually into the antapical stem, which is slightly curved ventrally and bears two very long attenuate spines, one upon each side. The antapex is porulate, and several sinuous ridge-like markings are found on the short neck. The head is elongated, oblique, with spreading lists with few ribs.

Nucleus much elongated. Chromatophores numerous, ellipsoidal.

Length, 670 μ; dorso-ventral diameter of midbody, 20 μ.

Station, 4605.

Amphisolenia brevicauda, sp. nov.

Plate 13, Fig. 79.

A very small species with elongated midbody and very short, straight, simple antapical.

The head is oblique, elongated, its length 2.5 times its dorso-ventral thickness. The neck is long and slender, its length 0.25 of the total length. The midbody is greatly elongated, slightly enlarged posteriorly, its length 0.5 of the total length, contracting abruptly to a short antapical extension whose length is less than that of the neck. The antapex is acute, without spines or modifications.

Length, 200 μ; transdiameter of midbody, 12 μ.

Station, 4740.

Amphisolenia clavipes, sp. nov.

Plate 14, Fig. 90.

A small but robustly proportioned species with small capitate head, long neck, tapering fusiform midbody not sharply delimited posteriorly. The antapex is bent abruptly to the right for a distance about equalling the greatest transdiameter of the midbody and terminates in a slight knob-like expansion with a dorsal and a ventral spinule.

Nucleus much elongated, chromatophores elongated, cylindrical.

Length, 235 μ; dorso-ventral diameter of midbody, 13 μ.

Station, 4736.

Amphisolenia curvata, sp. nov.

Plate 14, Fig. 87.

A stout species of medium size, with cushion-shaped head, fusiform body, and an antapical stem ventrally curved throughout, without terminal expansion.

A single small terminal spinule occurred on the left valve of individual drawn. Transverse lists low, spreading with few stout ribs, one of which passes down upon the side of the neck. The antapex is porulate and bears a few irregular reticulations on the thecal wall.

Nucleus small, broadly ellipsoidal. Chromatophores numerous, spheroidal.

Length, 460 μ; dorso-ventral diameter of midbody, 35 μ.

Station, 4605.

Amphisolenia dolichocephalica, sp. nov.

Plate 13, Fig. 82.

A large species with long very slender body with slight dorsal convexity. Head oblique, greatly elongated, its length nearly seven times its transverse and ten times its dorso-ventral diameter. Lists nearly horizontal, with numerous fine ribs. Neck about as long as the head, midbody tapering, fusiform. Antapex curved somewhat ventrally and to the right, with subcapitate termination bearing two straight spinules at the suture and decurrent hyaline ridges which pass quickly from the knob-like end to the slender cylindrical stem.

Nucleus greatly elongated.

Length, 1050 μ; dorso-ventral diameter of midbody, 22 μ; length of head, 82 μ.

Station, 4728.

Amphisolenia extensa, sp. nov.

Plate 13, Fig. 78.

A very large species with flattened very oblique head, relatively short neck, stout fusiform midbody and an enormously elongated antapical stem which is six times the length of the rest of the organism. The head is flattened ellipsoidal, with low spreading lightly ribbed transverse lists, a ribbed furrow, and coarsely ribbed longitudinal lists. The antapical stem is slightly convex dorsally and terminates in a slightly swollen subtruncate antapex without spines.

Nucleus elongated, chromatophores numerous, subspheroidal.

Length, 1380 μ; dorso-ventral diameter, 25 μ.

Station, 4699.

Amphisolenia laticincta, sp. nov.

Plate 13, Fig. 80.

A minute species with straight fusiform body. Head obliquely rounded, transverse furrow very wide, equalling the long axis of the head in width. Transverse lists low, spreading, with few faint ribs. Neck short, slightly exceeding the dorso-ventral diameter of the midbody in length. Midbody fusiform, forming nearly half of the total length. Antapical stem straight, with a single terminal spinule.

Nucleus elongated, chromatophores small, irregular.

Length, 112 μ; dorso-ventral diameter of midbody 9 μ; width of transverse furrow, 6 μ.

Station, 4740.

Amphisolenia lemmermanni, sp. nov.

Plate 14, Figs. 88, 89.

A species of medium size with broadly fusiform midbody, elongated, straight antapical stem with terminal expansion deflected to the right. The head is oblique, the neck about 1.4 times the dorso-ventral diameter of the midbody in length, and the terminal expansiōn of the antapex with three acute spines, one on the left side a short distance above the end at the point of deflection of the spreading antapex which is carried out on its dorsal and ventral angles in the other two spines. A slight knob-like expansion at the end of the straight section is connected by lists with the terminal spinules.

Length, 565 μ; dorso-ventral diameter of the midbody, 40 μ.

Station, 4730.

Amphisolenia palaeotheroides, sp. nov.

Plate 14, Fig. 84.

Body stout, its length 20–36 times the greatest dorso-ventral diameter, elongated fusiform with central swelling scarcely differentiated. Flagellar pore removed from the apex 0.12 of the total length. Antapex twisted slightly, terminating in an oblique asymmetrical enlargement with three large, stout, terminal spines. A similar stout spine at the beginning of the obliquity a short distance above the antapex. Collars with few ribs, transverse furrow ribbed and porulate.

Length, 426–605 μ; dorso-ventral diameter of body, 12–24 μ.

Station, 4732.

Amphisolenia projecta, sp. nov.

Plate 13, Fig. 77.

A small species of the *A. thrinax* group with bifurcated antapex whose ventral limb resembles that of *A. bifurcata* while the dorsal one is a knob-like prominence without spinules or lateral asymmetry. Body elongated with fusiform midbody. Total length 17 times the dorso-ventral diameter. Flagellar pore to apex 0.16 of the total length. Bifurcation to antapex 0.2 of the total length. Ventral limb of antapex fusiform, with four spinules, one lateral, and three terminal, limb deflected to the right at level of the lateral spinule. Dorsal limb equal to dorso-ventral diameter of midbody in length, clavate, its length twice its width.

Length, 185 μ; dorso-ventral diameter, 11 μ.

Station, 4701.

Amphisolenia quadrispina, sp. nov.

Plate 14, Fig. 86.

Body very long and slender, its length about 45 times the greatest dorso-ventral diameter, attenuate, fusiform, expanding posteriorly to a knob-like termination with four equidistant short incurved terminal spinules. Body constricted immediately anterior to the knob. Midbody not sharply delimited, about one third of the total length in length. Length of neck (girdle to flagellar pore) 0.13 of the total length, or four to five dorso-ventral diameters of the head without lists. Head capitate, transverse lists spreading, subhorizontal with few fine ribs, width of lists equals the transdiameter of the head. Terminal knob porulate.

Nucleus elongated, many small spheroidal chromatophores.

Length, 635–689 μ; dorso-ventral diameter of midbody, 14–17 μ.

Stations, 4613, 4722.

Amphisolenia quinquecauda, sp. nov.

Plate 13, Fig. 75.

This is a large species resembling *A. thrinax* but having five instead of three antapical ends. The neck and midbody form the apical third of the body, and the branches begin with the antapical third. The neck is short, but little longer than the dorso-ventral diameter of the midbody, which is stout, fusiform, its dorso-ventral diameter but slightly exceeding its transverse diameter.

The head is elongated, oblique, with spreading transverse lists heavily ribbed with about 20 ribs. The axis in the posterior third bends ventrally in a double curve and ends in a triangular antapex with short spinules on the angles. There is a dorsal spine a short distance from the antapex. The four branches are arranged in one plane in a single dorsal series and are all without enlargements, slightly curved, with the convex side dorsal. The first branch has an end similar to that of the axis, but the three slightly shorter ones of the middle group have but two small terminal spinules.

Nucleus elongated. Chromatophores small, elongated, very numerous.

Length, 835 μ; dorso-ventral diameter of midbody, 42 μ; length of first dorsal process about 300 μ.

Station, 4739.

Amphisolenia rectangulata, sp. nov.

Plate 14, Fig. 83.

A large species with short fusiform midbody, elongated oblique head, and much elongated antapical stem with very slight ventral curvature. The antapex terminates with very slight enlargement in rectangular form with the major axis dorso-ventral, and an acute spinule on each corner.

Nucleus much elongated; chromatophores spheroidal, numerous.

Differs from *A. quadrispina* in the more broadly fusiform midbody and in the form of the antapex, having no spheroidal enlargement.

Length, 735 μ; dorso-ventral diameter of midbody, 24 μ.

Station, 4740.

Amphisolenia schroederi, sp. nov.

Plate 13, Fig. 81.

A medium-sized species with capitate head, elongated fusiform midbody, and antapex with two spinules.

The body is elongated, its length 25 times the dorso-ventral diameter. The head is small, spheroidal, its diameter less than that of the midbody. The neck is about 0.16 of the total length and the midbody is not differentiated. The antapex is not enlarged, is truncate, and deflected to the right. It bears on the angles two stout terminal spines both of which are on the right valve.

This species differs from *A. bispinosa* in the location of the terminal spines and in the form of the head.

Length, 510 μ; dorso-ventral diameter of the midbody, 20 μ.

Station, 4737.

TRIPOSOLENIA, Kofoid.[1]

Dinophysidae with equal or unequal valves. With three subequal processes from a laterally compressed central midbody, one anterior and two posterior. The anterior process consists of the head, neck, protuberant cytopharyngeal region, and a short process from the midbody. The posterior processes are two symmetrically placed curved antapical horns, respectively dorsal and ventral in origin, with or without marginal tubercles or terminal spinules. The head and neck resemble those of *Amphisolenia.* The essential difference between *Amphisolenia* and *Triposolenia* lies in the presence in the latter of balanced antapicals arising from a midbody containing the greater mass of protoplasm and the nucleus. In all known forms of *Amphisolenia* the midbody is fusiform and bears no dorsal horn, the dorsal horn, if present, arising from the antapical process.

The thecal wall is structureless, pitted, or rarely locally reticulate.

The nucleus is located in the midbody. Chromatophores lacking (?) or of pale greenish-yellow color.

Sparingly distributed in warm temperate and tropical waters, but rarely taken at the surface.

Triposolenia longicornis, sp. nov.

Plate 17, Fig. 101.

A very large species with long process and long antapical horns, small triangular midbody, and flattened head.

[1] Kofoid, C. A. Dinoflagellata of San Diego Region II. On Triposolenia, a new genus of the Dinophysidae. Univ. of Calif. Pubs. Zoöl., 3, p. 99–133, plates 15–19. 1906.

The midbody is laterally compressed, triangular in lateral view with the anterior margins subequal and both concave. The postmargin is but slightly convex. The anterior process is long, its length equalling that of an anterior margin. The cytopharyngeal margin is expanded ventrally to twice the dorso-ventral diameter of the neck, which is slender, its length being nearly one and one half times that of the process. It is curved dorsally in a regular arc, which continues the curvature of the dorso-ventral margin of the midbody. The head is flattened and the transverse furrow is slightly constricted.

The antapicals arise from the postero-lateral angle of the midbody and spread latero-posteriorly in a broad curve. The tips are somewhat incurved, but there is no sigmoid flexure as in *T. fatula*. The greatest distance between the antapicals is 0.63, and that between the tips 0.5 (of the total length). The antapicals are truncate in dorsal or ventral view, with short lateral terminal spinules. In lateral view they are somewhat rounded. Both horns are deflected to the left distally, the dorsal somewhat more than the ventral.

The lists are heavily and sparingly ribbed and the thecal wall shows no structural differentiation.

Length to postmargin of midbody, 125 μ; to tip of ventral antapical, 275 μ.

Stations, 4385, 4711.

Its long process and horn are evidently adaptive to the higher temperatures of its habitat.

Triposolenia fatula, sp. nov.

Plate 17, Fig. 102.

A large species resembling *T. ambulatrix* with less asymmetry of the spreading antapicals and a constricted region in the anterior part of the neck.

The midbody is low triangular in lateral view with nearly straight margins, the posterior longer, and the antero-ventral shorter than the antero-dorsal. The anterior process is long, its length exceeding the altitude of the midbody. The neck is very long and slender and its distal fifth is reduced in dorso-ventral diameter and bent dorsally to a slight extent. Its length is about 0.2 of the total length. The head is spheroidal and relatively small.

The antapicals are very long, their length being 4.5 times the altitude of the midbody. They are slightly asymmetrical, the dorsal is slender, does not converge or show a sigmoid flexure distally, as does the ventral. The distance between the tips is five times the altitude of the midbody. Distally the dorsal antapical bends to the left, and the ventral one only slightly at the very end. The tips are truncate and minutely spinulate.

The thecal wall is hyaline, structureless, and the collars and lists are heavily but sparingly ribbed.

Length to postmargin of midbody, 90 μ ; to tip of ventral antapical, 190 μ.

Station, 4587.

Triposolenia ambulatrix, sp. nov.

Plate 4, Fig. 24.

A medium-sized species of the *T. bicornis* type with both antapical horns deflected dorsally, especially the dorsal one.

The midbody is laterally compressed, subtriangular in lateral view with anterior process and antapicals arising from the angles as in *T. bicornis.* Its sides are all convex and the anterior process arises abruptly from somewhat squarish shoulders. The head is spheroidal, and the neck long, slender, and convex ventrally. There is a large ventral protuberance about the flagellar pore.

The ventral antapical is abruptly deflected postero-dorsally and forms a slight sigmoid curve which is less pronounced distally. Its tip is acute and it is deflected to the *right* distally. The dorsal antapical is not bent to form a balanced horn, in reverse, as in *T. bicornis,* but is thrown dorso-posteriorly with a slight anterior convexity. Its tip is truncate and bears two minute spinules. It is deflected to the *left* distally. There are a few distally located tubercles on the dorsal and ventral margins of the antapicals.

Length to postmargin of midbody, 95 μ ; to tip of ventral antapical, 165 μ.

Station, 4711.

Histioneis carinata, sp. nov.

Plate 16, Fig. 98.

Somewhat resembling *H. biremis* Stein as figured by Murray and Whitting [1] in its bird-shaped body, and in the absence of a postero-dorsal prolongation. The anterior collar is less abundantly ribbed, and both it and the posterior one are asymmetrical, being lower at the right end. There is no fin dorsal to the posterior rib. The areoles on the midbody are more numerous, being 11 by 20 to 8 by 15 in *H. biremis.* There is no ventro-marginal rib in the posterior wing.

Length, 90 μ ; dorso-ventral diameter of midbody, 50 μ.

Station, 4724.

Histioneis garretti, sp. nov.

Plate 16, Fig. 97.

A small species resembling *H. para* Murr. et Whitt. but differing from it in the presence of a fin on the dorsal side of the posterior rib. There are reticulations in the basal part of the anterior collar, and along the dorsal ribs of the posterior collar. The ventral and posterior fins are also more or less reticulate. Both collars closed ventrally and dorsally.

Length, 63 μ ; dorso-ventral diameter, 38 μ.

Station, 4732.

[1] New Peridiniaceae from the Atlantic. Trans. Linn. Soc. Lond. Bot., **32,** Plate 32, Fig. 6.

Histioneis josephinae, sp. nov.

Plate 15, Fig. 91.

A large species with deeply concave midbody and broad, subcylindrical, posterior collar as in *H. helenae.* This species is especially marked by the enormous development of the various wings and by the presence in their peripheral portions of arborescent thickenings which resemble a coral necklace in form. In addition to an enormously developed posterior dorso-ventral wing there is also present a pair of transverse wings arising from the posterior rib, and a great accessory lateral on the left side, the latter as well as the ventral wing being provided with an excessively hyaline outer segment. Each of these wings bears one or several coral-like thickenings at the termination of ribs or in peripheral regions. The most striking development of organs of flotation among the Dinoflagellidia.

Length, 115 μ; dorso-ventral diameter, including wings, 80 μ.

Station, 4699.

Histioneis longicollis, sp. nov.

Plate 16, Fig. 100.

A small species resembling immature stages of *H. cymbalaria* but differs from it in having a more rotund body, a postero-ventral fin deflected ventrally from the axis and without ventral marginal rib. The posterior collar bears a hyaline list on its anterior margin outside of the rib. Both collars are closed both dorsally and ventrally by hyaline membranes. The body wall is not pitted or reticulated.

Length, 70 μ; dorso-ventral diameter of body, 24 μ.

Station, 4711.

Histioneis navicula, sp. nov.

Plate 16, Fig. 96.

A medium-sized species with boat-shaped body resembling that of *H. cymbalaria* but longer and more slender. The posterior collar resembles that of *H. biremis*, but both it and the anterior are complete both dorsally and ventrally, there being no gap in the suture line. The anterior collar is asymmetrical, being shorter along the right margin. This collar is somewhat reticulated and ribbed. The ventral fin has a single ventral and one posterior rib, the latter branching at the tip. Phaeosomes in the anterior chamber.

Length, 86 μ; dorso-ventral axis of body, 62 μ.

Station, 4734.

Histioneis paulseni, sp. nov.

Plate 15, Fig. 94.

A small species related to *H. remora.* It differs from it in having the body more elongated in the dorso-ventral direction, a wider and relatively shorter

postero-ventral fin, in the absence of reticulations on the fins, and in the presence of a hyaline border on the anterior margin of the posterior collar. Both dorsal and ventral collar clefts in both collars are closed by delicate hyaline membranes.

Length, 64 μ ; dorso-ventral diameter of body, 33 μ.

Station, 4711.

Histioneis pulchra, sp. nov.

Plate 16, Fig. 99.

A medium-sized species of the general form of *H. mitchellana* but differing from it in the character of the reticulations of the wings and collars. In *H. pulchra* the reticulations are coarse, irregular, and more or less incomplete. They are found on the anterior parts of the two collars, on the posterior part of the ventral, and on the posterior wings. In *H. mitchellana* the reticulations are fine, delicate, and more or less regular.

Length, 135 μ; dorso-ventral diameter, 60 μ.

Station, 4730, 4734, 4742.

Histioneis reticulata, sp. nov.

Plate 15, Fig. 95.

A small species resembling *H. crateriformis* Stein but differing from it in the much lower anterior collar, a higher, more recurved anterior process from the body, in the presence of a subregular polygonal reticulum on parts of the posterior collar and on the ventral fins, and in its straight posterior rib.

Both ventral fins are relatively low. The left has two ribs, both of which are straight. The middorsal and midventral clefts of the posterior collar are both closed by membranes, the former with five equidistant transverse ribs running across the closing membrane.

Length, 115 μ ; dorso-ventral diameter, 85 μ.

Stations, 4699.

Ornithocercus carolinae, sp. nov.

Plate 15, Fig. 92.

A medium-sized species resembling *O. magnificus* but differing from it in the following particulars: the posterior wing has 12–14, rarely 9–15, light ribs of uniform size evenly distributed without prominent midribs to the marginal and median projections. These ribs are more slender and more numerous than those in *O. magnificus*. The anterior collar has numerous (twenty or more) primary ribs, with intercalated secondary and tertiary ones. The right and left ventral wings are in old (?) individuals reticulated. Reticulations may also be found in the middorsal region of the posterior collar, at the base of the anterior one, and on the dorsal margin of the posterior wing.

Length, 100 μ; dorso-ventral diameter, 65 μ.

Stations, 4719, 4721, 4722, 4724, 4740.

Ornithocercus heteroporus, sp. nov.

Plate 12, Fig. 70.

A minute species with slightly oblique axis, relatively few ribs in the collar, posterior wing confined to the ventral side of the midbody, with marginal ribs. Pores heterotypical.

Midbody rotund, laterally compressed, its length 1.16 times the dorso-ventral and 1.3 times the transverse diameter. Anterior collar flaring with few ribs, reticulated basally. Posterior collar with 8 ribs, a row of coarse reticulations at its base and along the base of the right ventral wing (obsolete in individual figured). Left ventral reticulate at base. Posterior wing confined to ventral side with marginal ribs and peripheral seam. Thecal wall porulate with evenly distributed pores, one in 6 or 8 darker than the others.

Length, 50 μ; dorso-ventral diameter, including fin, 37 μ.

Station, 4699.

Ornithocercus serratus, sp. nov.

Plate 15, Fig. 93.

A large species with rounded posterior wing with 4–5 equidistant rounded or acute apices.

This species differs from all others in the large number and the regularity of the marginal prominences of the posterior wing, each of which is the termination of a single rib. There is as a rule no marginal connecting rib as often in *O. magnificus, steini*, and *quadratus.* The dorsal margin of the posterior wing is more rounded, not angular or squarish as in other species. The ribs are also more regularly spaced, freer from branching and other irregularities, and the posterior wing has less intercostal reticulation. Terminal reticular brushes appear on some individuals at the ends of the ribs.

Length, 110–145 μ; dorso-ventral diameter, 95–130 μ.

Stations, 4613, 4742.

Amphilothus quincuncialis, sp. nov.

Plate 1, Fig. 10.

A minute species of ellipsoidal form, median girdle, with skeletal elements with quincuncial arrangement in the hypotheca.

Body broadly ellipsoidal, its length 1.6 times the transverse diameter. Epitheca and hypotheca subequal. Epitheca a low cone with very constricted blunt apex, its altitude 0.8 of its transdiameter.

Hypotheca a low dome with very broadly rounded antapex, its altitude 0.8 times its transdiameter.

Girdle 0.1 of the total length in width, nearly median in position, deeply impressed, without lists, horizontal, without displacement. Longitudinal furrow straight, a wide shallow furrow, 0.8 of the length of the body in length, equally extended on the two sides of the girdle.

Skeletal elements superficial, diamond-shaped in hypotheca, 5–6 rows, with primary nodal tubercles and smaller internodal beads and openings in each area, with irregular mesh between pores and margins. In the epitheca there are about 16 subregular meridional ridges with pores between.

Length, 33 μ ; diameter, 20 μ.

Anchorage at Panama, surface.

EXPLANATION OF PLATES.

All figures have been drawn with camera lucida. They have been drawn in ink for reproduction by Mr. A. B. Streedain from pencil sketches made by Miss E. J. Rigden, with few exceptions, those designated in the explanations as drawn from life being made by the author.

ABBREVIATIONS.

a. c., anterior collar.
a. l. f., accessory lateral fin.
ant., antapex.
ap. p., apical pore.
arb., arborescent thickening.
a. v., anterior valve.
car., carina.
D., dorsal side.
d. ant., dorsal antapical horn.
f. p., flagellar pore.
h., head.
L., left side.
l., lens.
l. f., longitudinal furrow.
l. i. p., left intercalary plate.
l. v. f., left ventral fin.
mb., midbody.
mel., melanosome.
n., nucleus.
nk., neck.
o. s., outer segment.
p., pore.
p. c., posterior collar.
p. can., pore canals.
p. f., posterior fin.
ph., phaeosomes.
p. v., posterior valve.
R., right side.
r. l. f., right lateral fin.
r. v. f., right ventral fin.
s., suture.
sk. el., skeleton elements.
sp., spine.
th. w., thickened wall.
tr. f., transverse furrow.
v., ventral side.
v. a., ventral area.
v. ant., ventral anterior horn.
v. f., ventral fin.
v. p., ventral pore.
v. pl., ventral plate.

PLATE 1.

Fig. 1. *Prorocentrum curvatum*, sp. nov., lateral view. × 565. From life.
Fig. 2. The same, anterior face. × 565.
Fig. 3. *Pyrocystis fusiformis*, forma *biconica*, f. nov. × 100.
Fig. 4. *Pyrocystis acuta*, sp. nov. × 62.
Fig. 5. *Pyrocystis robusta*, sp. nov. × 320.
Fig. 6. *Pyrocystis semicircularis* (Schröder), lateral view of yoked pair. × 100.
Fig. 7. *Pouchetia panamensis*, sp. nov., ventral view. × 895. From life.
Fig. 8. *Ptychodiscus carinatus*, sp. nov., ventral view. × 450. From life.
Fig. 9. Lateral view of the same. × 450.
Fig. 10. *Amphilothus quincuncialis*, sp. nov. Oblique view of right face. × 895. From life.

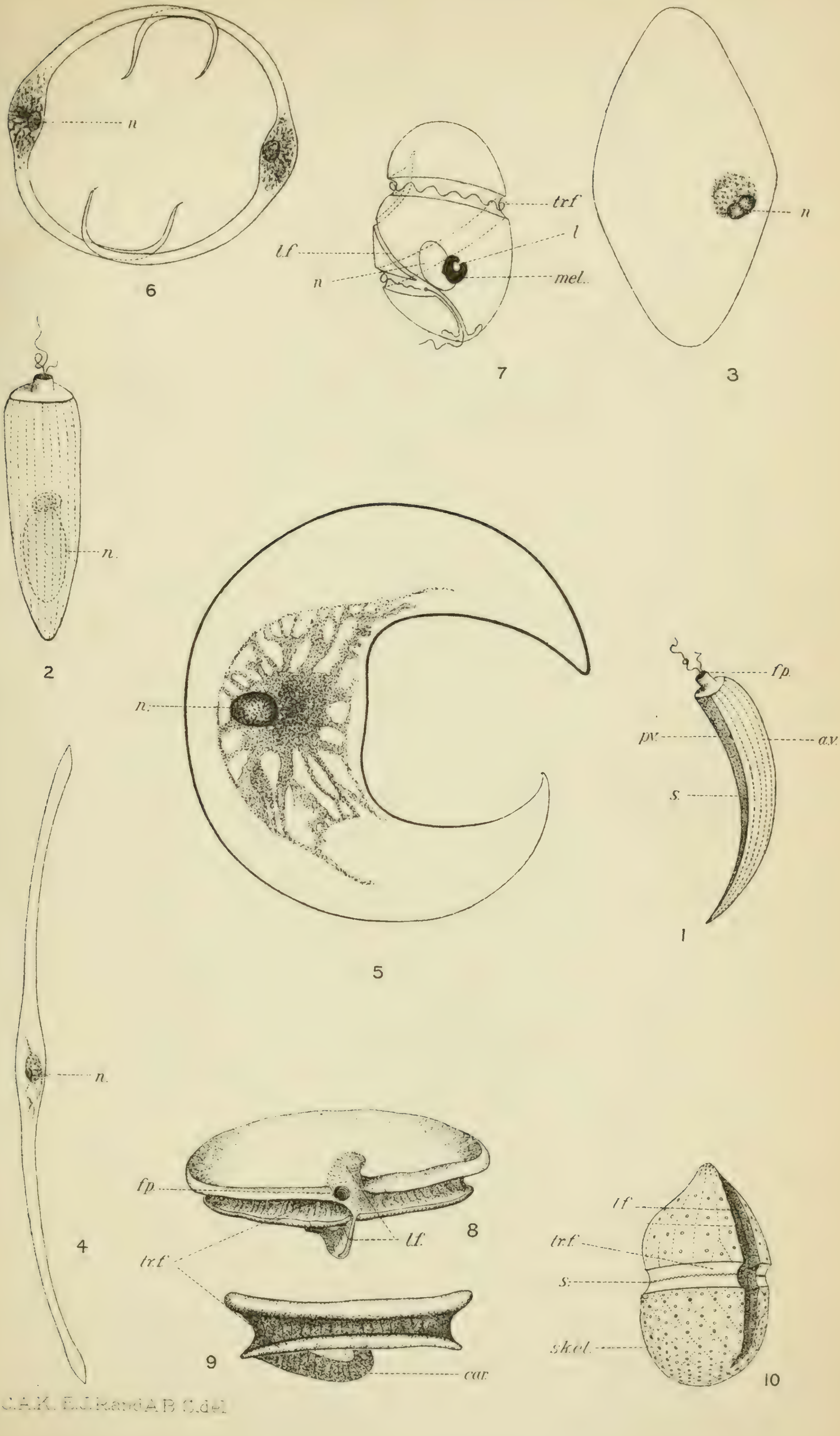

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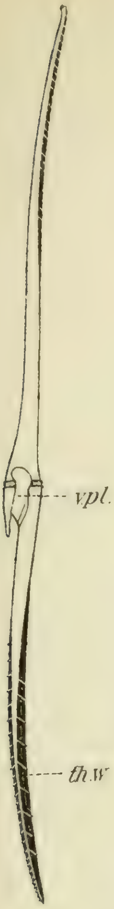
PLATE 2.

Fig. 11. *Podolampas reticulata*, sp. nov., ventral face. × 935.
Fig. 12. *Ceratium pennatum*, sp. nov., forma *propria*, f. nov., ventral face. × 100.
Fig. 13. *Ceratium pennatum* forma *inflata*, f. nov., ventral face. × 100.
Fig. 14. *Ceratium pennatum* forma *falcata*, f. nov., ventral face. × 100.
Fig. 15. *Steiniella inflata*, sp. nov., ventral face. × 450.
Fig. 16. *Ceratium ehrenbergi*, sp. nov., ventral face. × 450.



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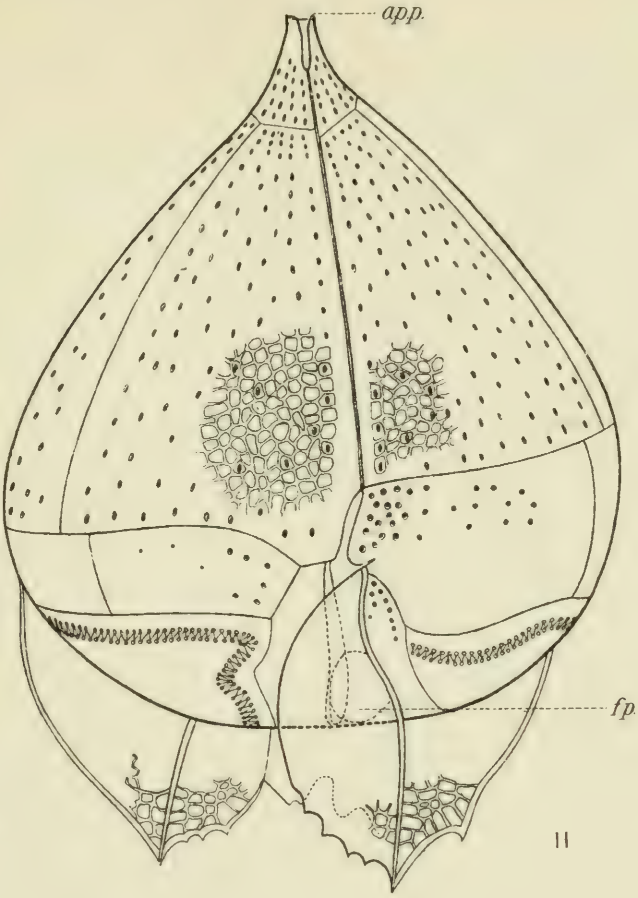

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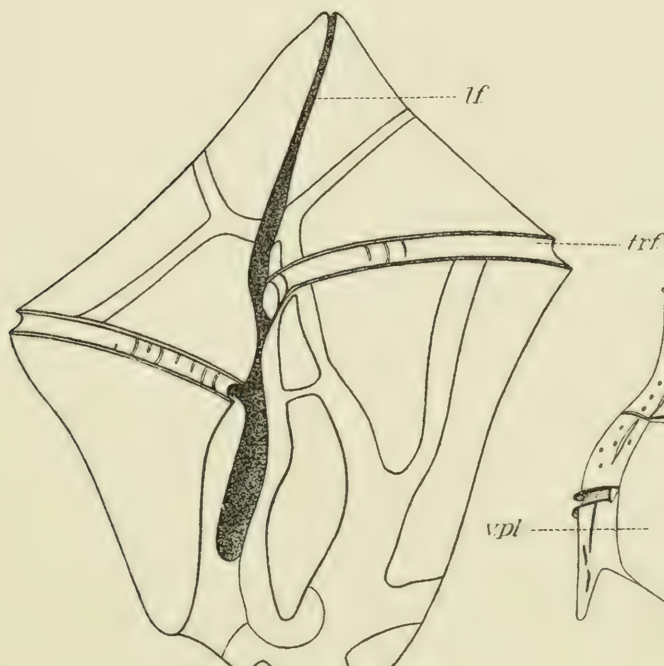

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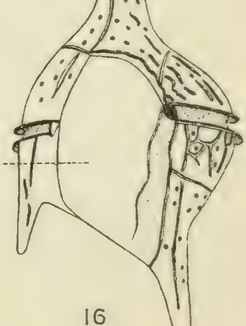

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PLATE 3.

Fig. 17. *Ceratium lanceolatum*, sp. nov., ventral view. × 935.
Fig. 18. *Ceratium schröteri* Schröder, view of dextral face. × 315.
Fig. 19. Ventral view of the same. × 315.
Fig. 20. *Ceratium tricarinatum*, sp. nov., dorsal view. × 210.
Fig. 21. *Ceratium pacificum* Schröder, dorsal view. × 285.
Fig. 22. *Ceratium bigelowi*, sp. nov., dorsal view. × 100.
Fig. 23. *Ceratium scapiforme*, sp. nov., dorsal view. × 205.

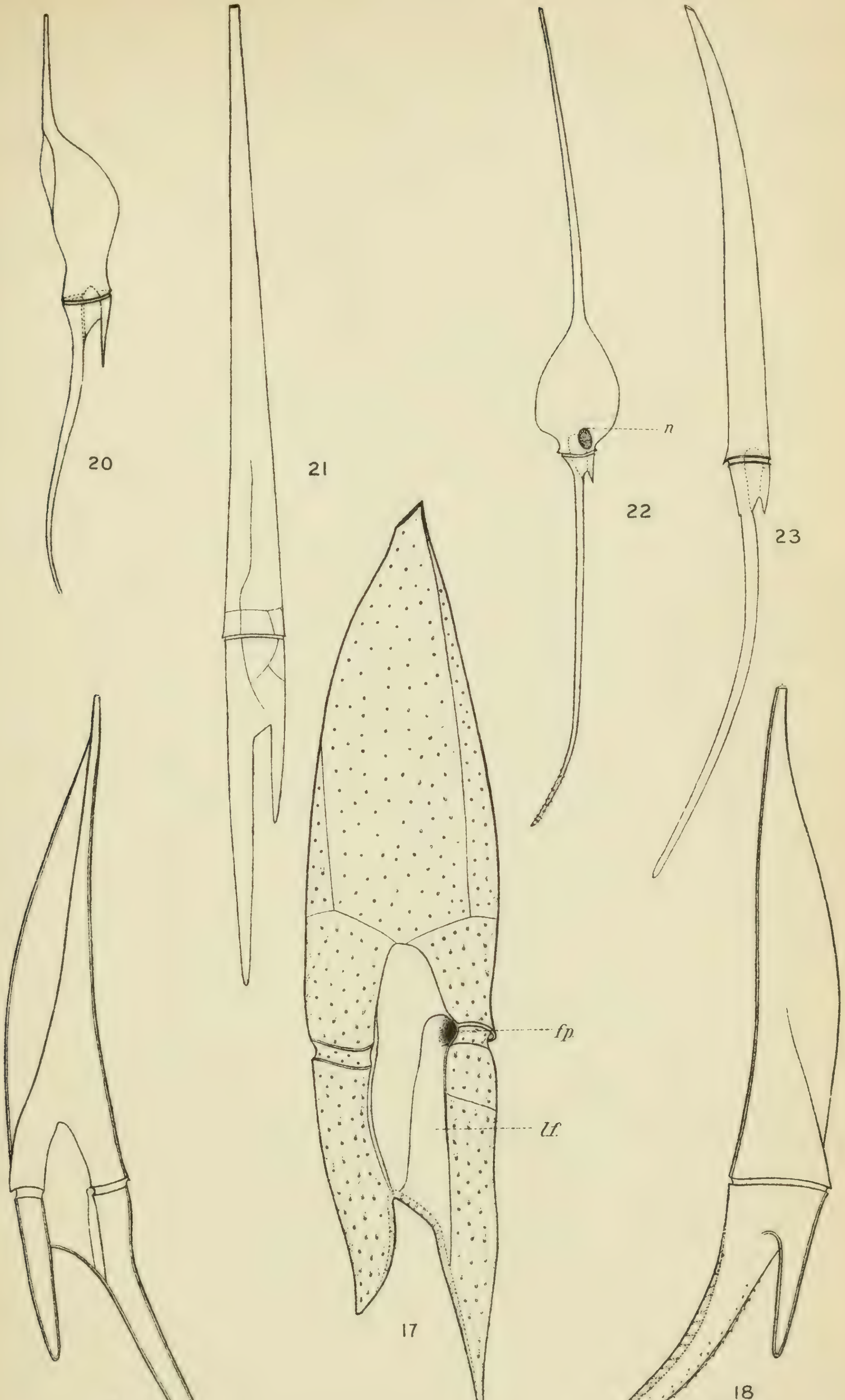

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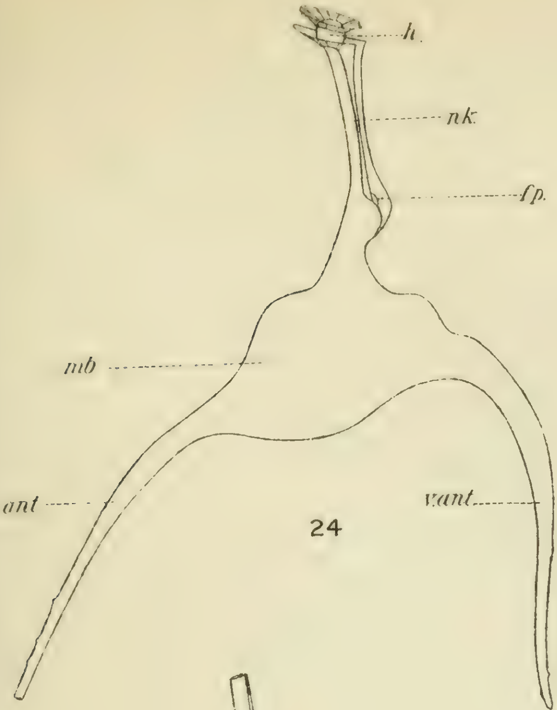
PLATE 4.

Fig. 24. *Triposolenia ambulatrix*, sp. nov., dextral face. × 450.
Fig. 25. *Ceratium dilatata* (Karsten), ventral face. × 450.
Fig. 26. *Ceratium axiale*, sp. nov., ventral face. × 450.
Fig. 27. *Ceratium claviger*, sp. nov., ventral face. × 285. From life.



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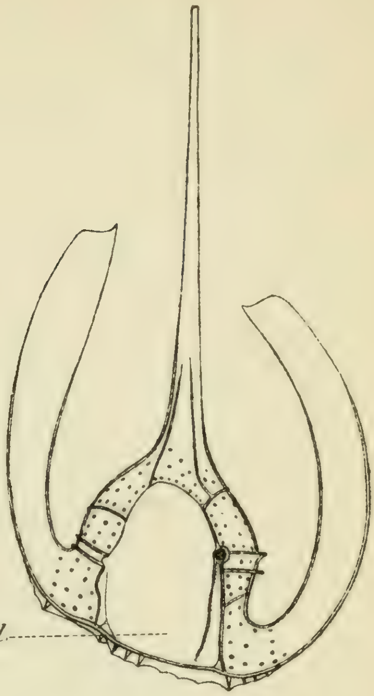

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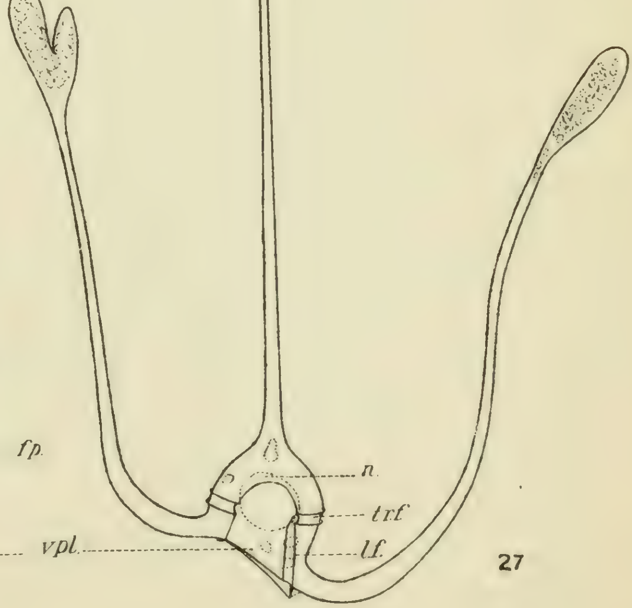

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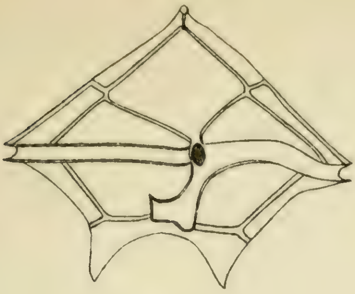
PLATE 5.

Fig. 28. *Peridinium grande*, sp. nov., dorsal face. × 450.
Fig. 29. *Peridinium murrayi*, sp. nov., ventral face. × 295. From life.
Fig. 30. *Peridinium fatulipes*, sp. nov., ventral face. × 565.
Fig. 31. *Peridinium latissimum*, sp. nov., ventral face. × 295. From life.
Fig. 32. Same, diagrammatic apical view. × 295.
Fig. 33. *Peridinium longispinum*, sp. nov., dorsal face. × 450.
Fig. 34. *Peridinium tenuissimum*, sp. nov., ventral face. × 450.



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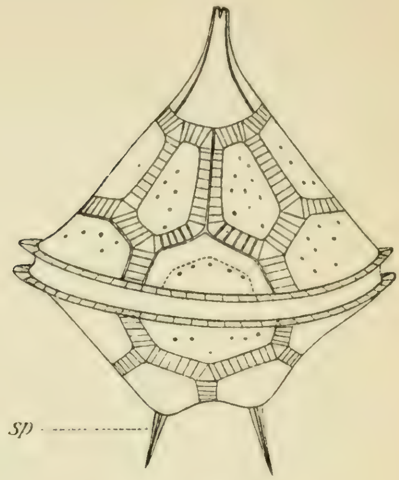

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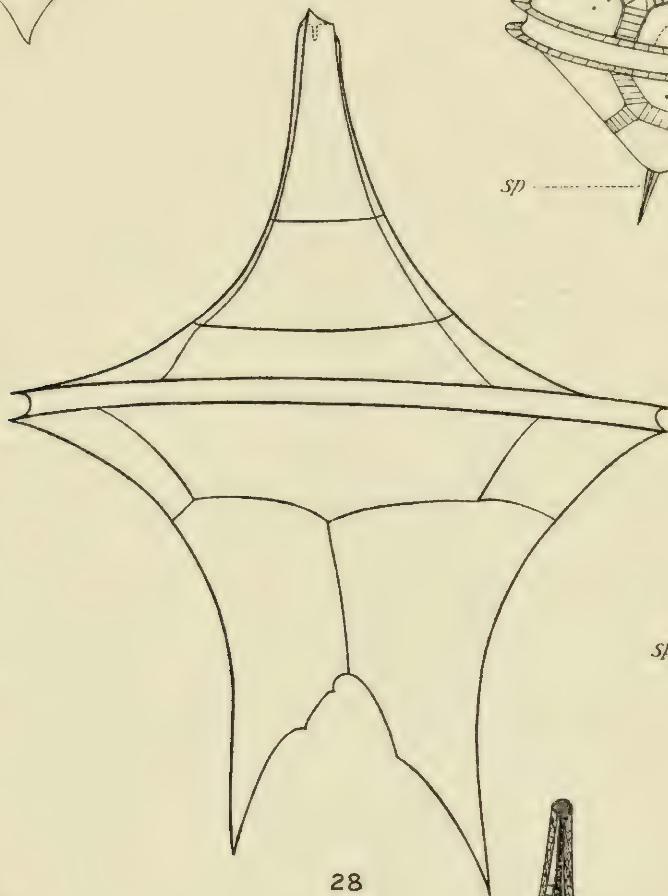

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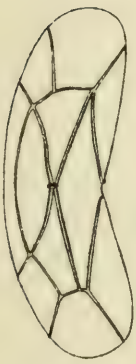

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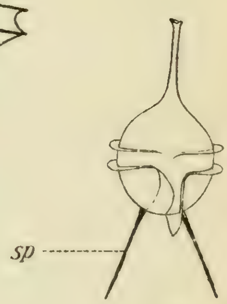

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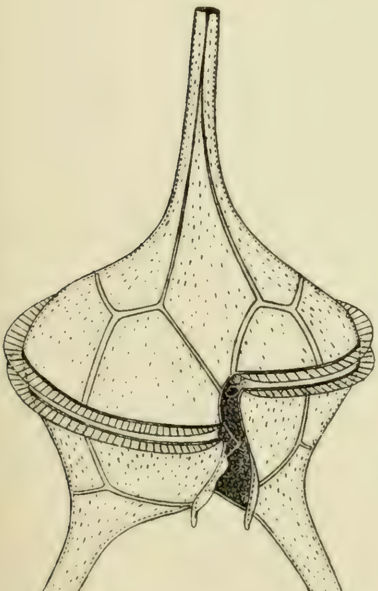

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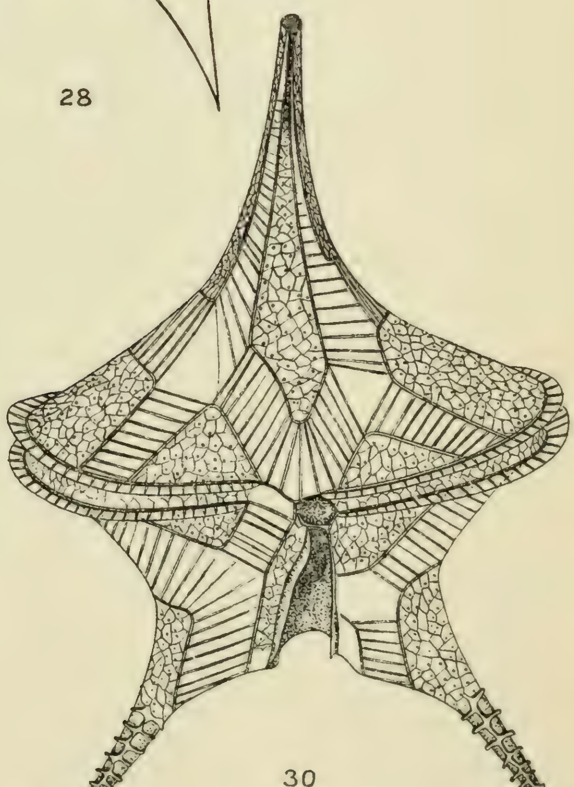

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PLATE 6.

Fig. 35. *Heterodinium agassizi*, sp. nov., ventral face. × 450.

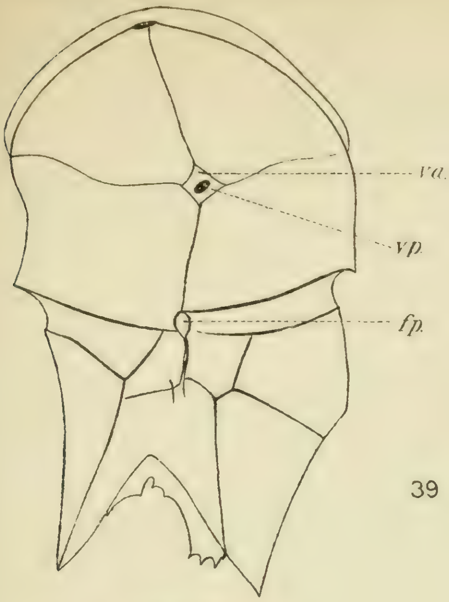
Fig. 36. *Heterodinium expansum*, sp. nov., ventral face. × 565

Fig. 37. *Heterodinium gesticulatum*, sp. nov., forma *typica*, f. nov., ventral face. × 440.

Fig. 38. *Heterodinium gesticulatum*, sp. nov., forma *extrema*, f. nov., ventral face. × 450.

Fig. 39. *Heterodinium gesticulatum*, sp. nov., forma *mediocris*, f. nov., ventral face. × 450.

Fig. 40. *Heterodinium gesticulatum*, sp. nov., forma *deformata*, f. nov., dorsal face. × 450.



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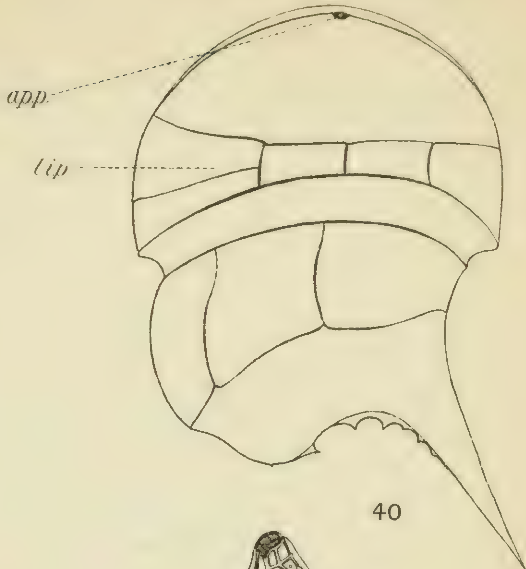

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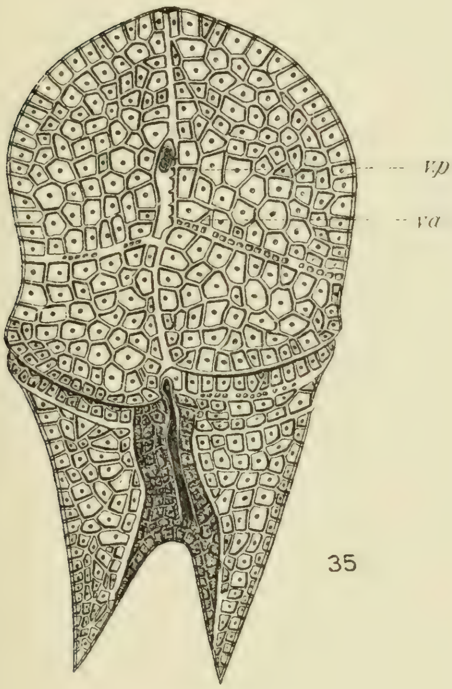

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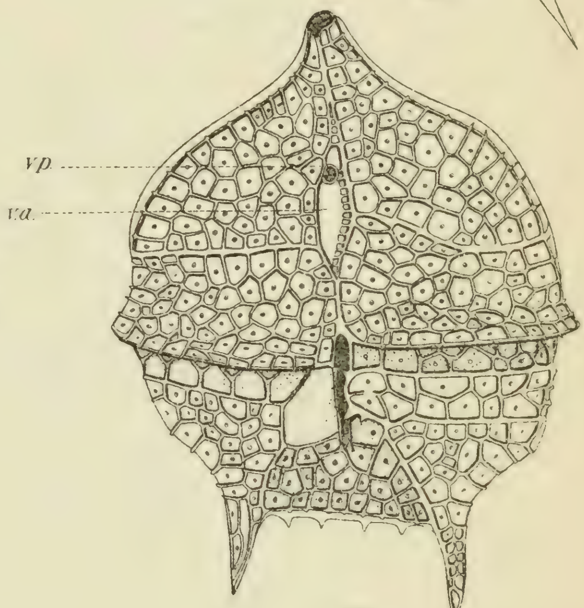

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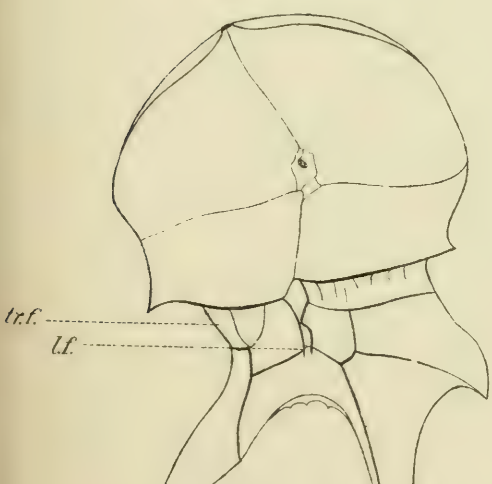

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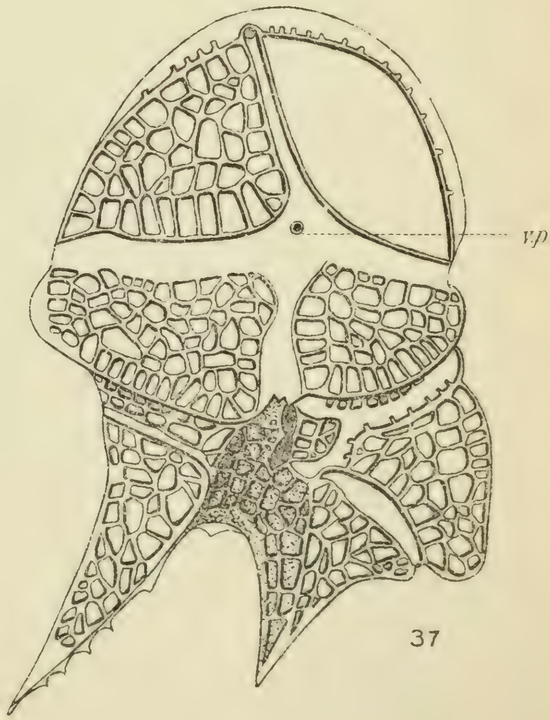

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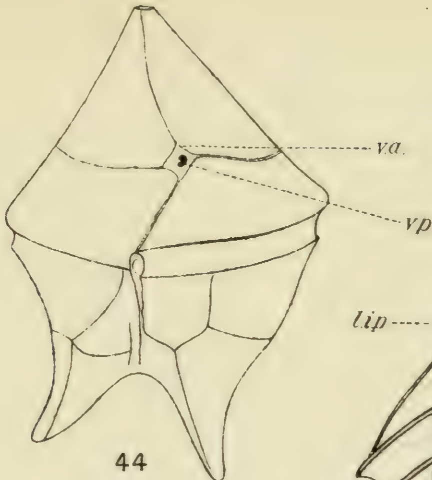
PLATE 7.

Fig. 41. *Heterodinium praetextum*, sp. nov., dorsal face. × 405.
Fig. 42. *Heterodinium hindmarchi* forma *maculata*, f. nov., ventral face. × 405.
Fig. 43. *Heterodinium calvum*, sp. nov., ventral face. × 405.
Fig. 44. *Heterodinium longum*, sp. nov., ventral face. × 405.
Fig. 45. *Heterodinium fides*, sp. nov., dorsal face. × 405.
Fig. 46. *Heterodinium laticinctum*, sp. nov., view of right side. × 405.



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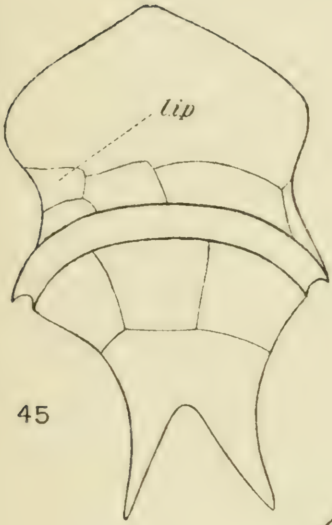

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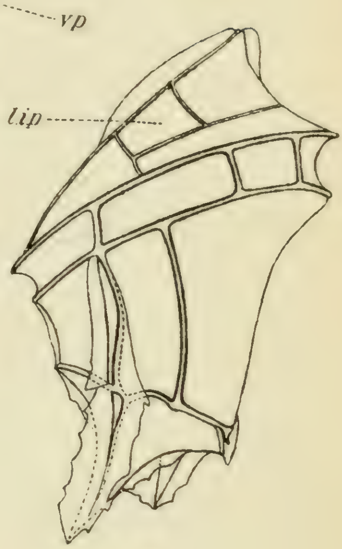

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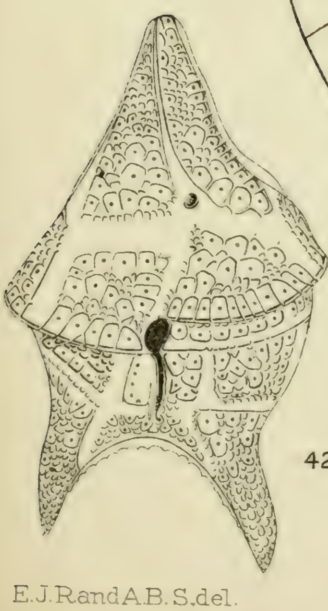

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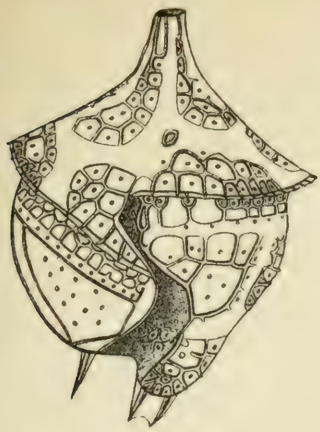
PLATE 8.

Fig. 47. *Heterodinium fenestratum*, sp. nov., ventral face. × 840.
Fig. 48. *Heterodinium curvatum*, sp. nov., ventral face. × 840.
Fig. 49. *Heterodinium superbum*, sp. nov., ventral face. × 840.
Fig. 50. *Heterodinium obesum*, sp. nov., ventral face. × 840.
Fig. 51. *Heterodinium globosum*, sp. nov., ventral face. × 840.



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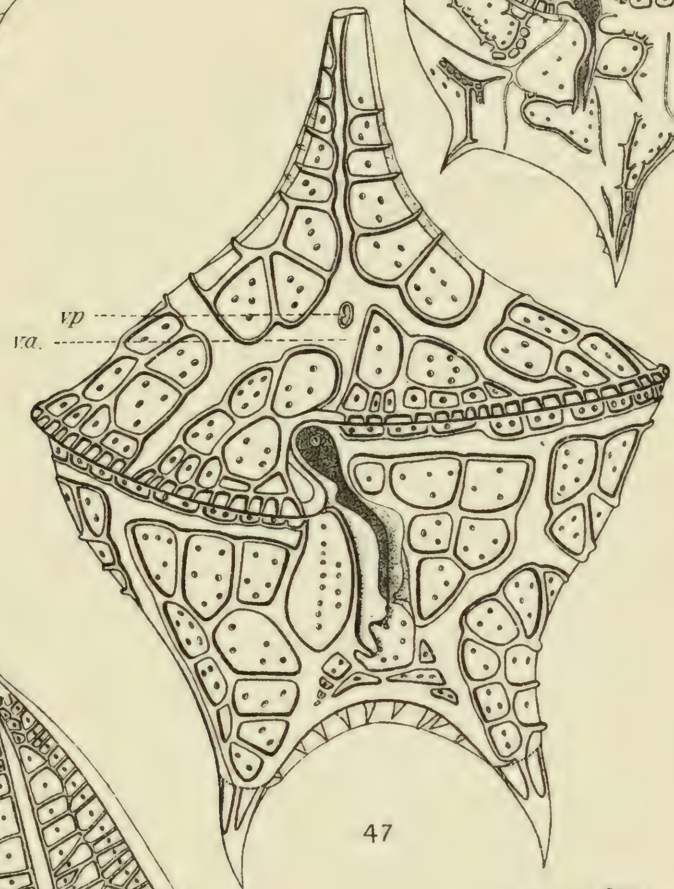

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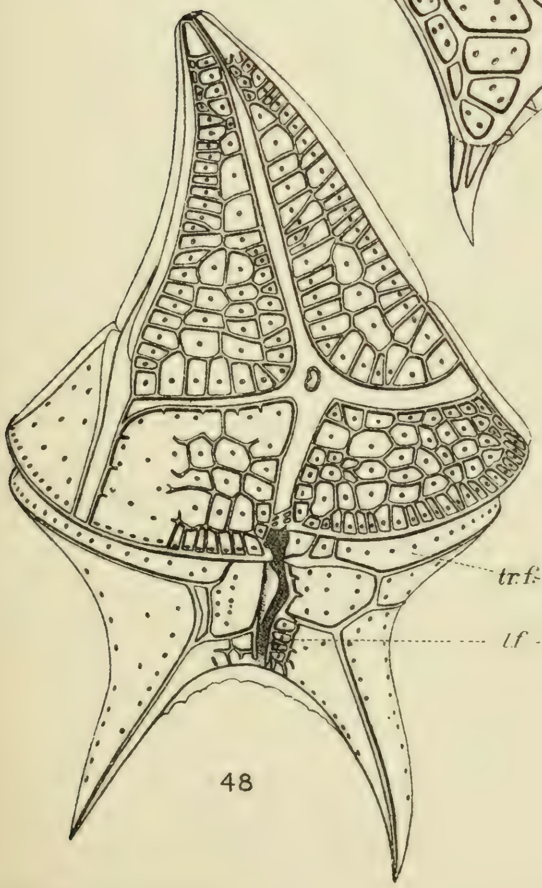

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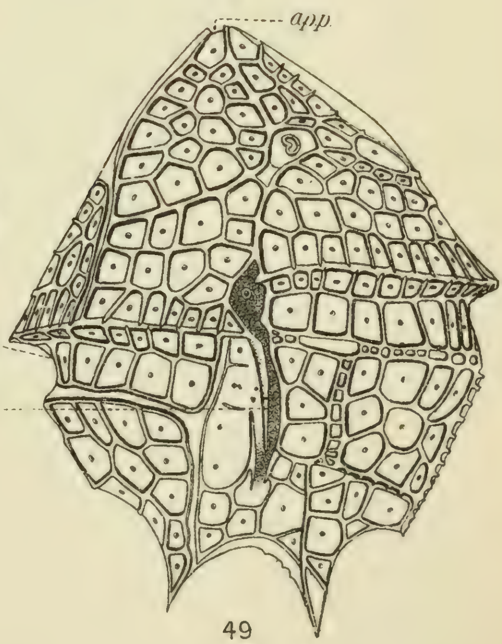

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PLATE 9.

Fig. 52. *Centrodinium elongatum*, sp. nov., left face. × 450.
Fig. 53. *Centrodinium deflexum*, sp. nov., ventral view. × 450.
Fig. 54. Same, left face. × 450.
Fig. 55. *Murrayella rotundata*, sp. nov., view of right face. × 442.
Fig. 56. *Murrayella globosa*, sp. nov., ventral face. × 935.
Fig. 57. *Murrayella spinosa*, sp. nov., ventral face. × 935.
Fig. 58. *Murrayella punctata* (Cleve), ventral face. × 935.

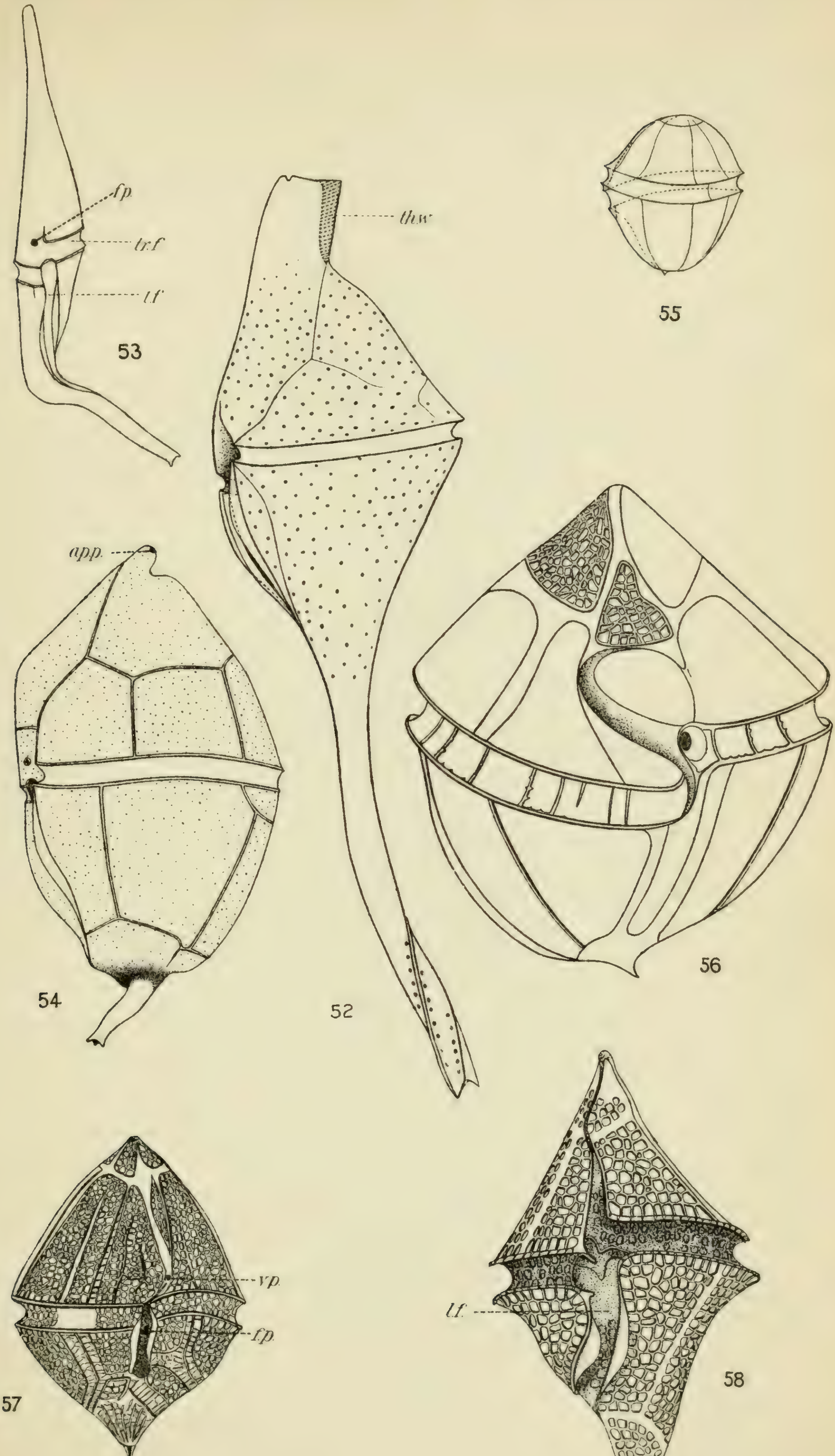

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PLATE 10.

Fig. 59. *Oxytoxum gigas*, sp. nov., ventral face. × 450.

Fig. 60. *Oxytoxum turbo*, sp. nov., ventral face. × 935.

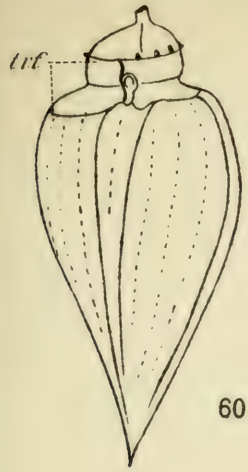
Fig. 61. *Oxytoxum curvicaudatum*, sp. nov., sinistral face. × 442. From life.

Fig. 62. *Oxytoxum subulatum*, sp. nov., dextral face. × 565.

Fig. 63. *Oxytoxum compressum*, sp. nov., oblique view of sinistral face. × 442. From life.

Fig. 64. *Oxytoxum cristatum*, sp. nov., sinistral face. × 442. From life.

Fig. 65. *Oxytoxum challengeroides*, sp. nov., ventral view, reticulations shown only on midventral postcingular plate. × 935.



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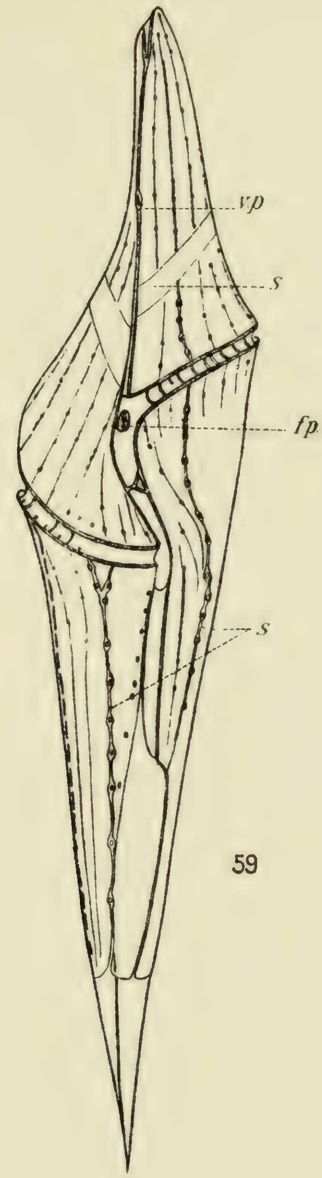

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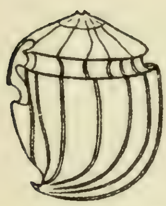

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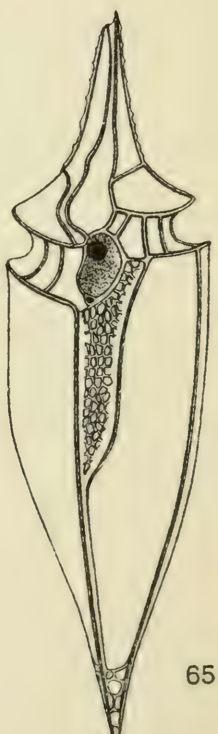

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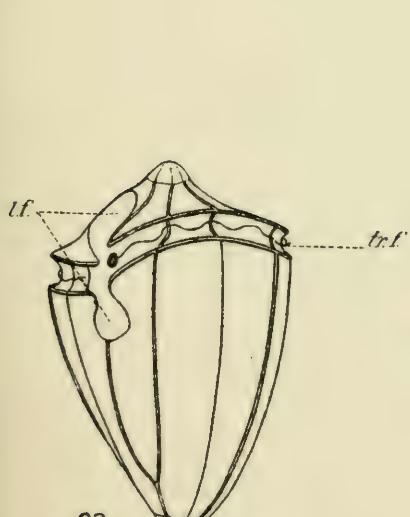

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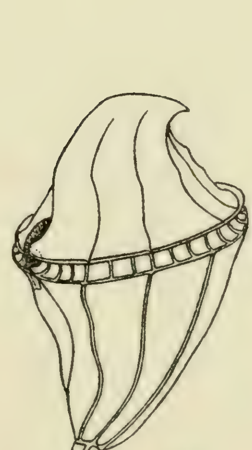

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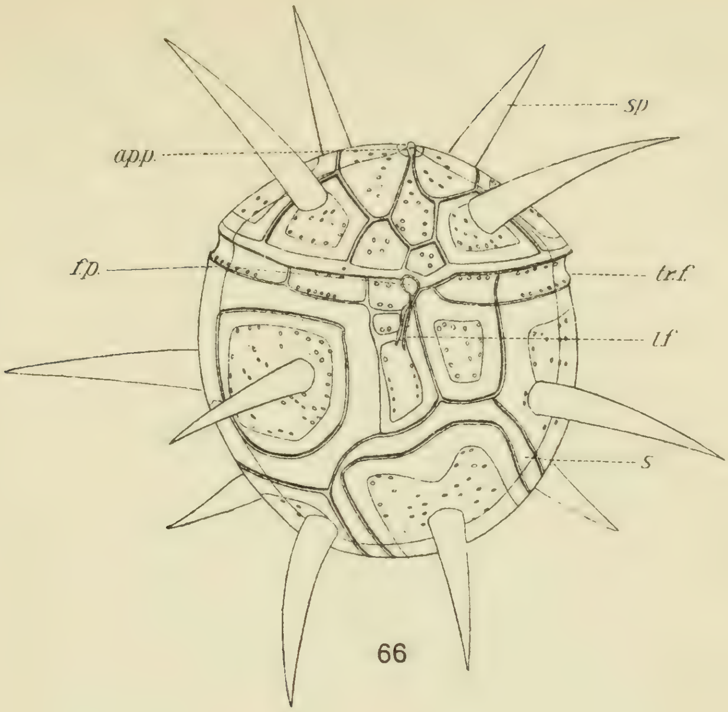
PLATE 11.

Fig. 66. *Acanthodinium spinosum*, sp. nov., ventral view. $\times$ 935.
Fig. 67. *Acanthodinium caryophyllum*, sp. nov., ventral view. $\times$ 935.



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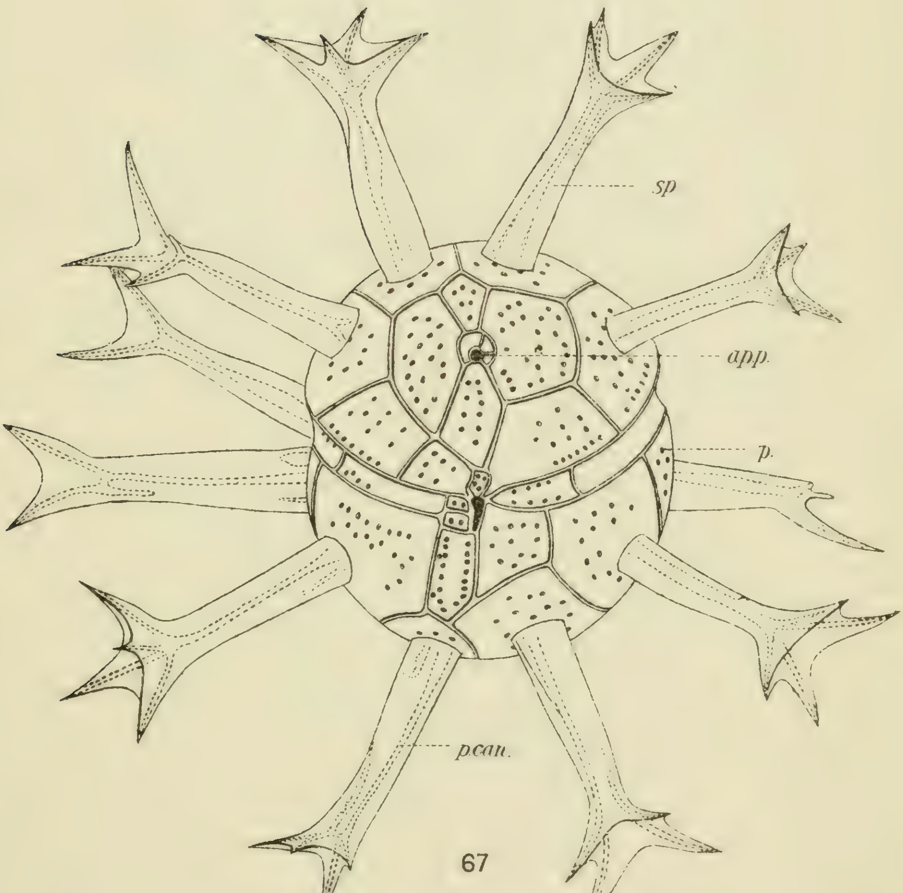

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PLATE 12.

Fig. 68. *Phalacroma ultima*, sp. nov., dextral view. × 935.

Fig. 69. *Phalacroma lenticula*, sp. nov , dextral face. × 450. Reticulations only partially shown.

Fig. 70. *Ornithocercus heteroporus*, sp. nov., dextral face. × 935.

Fig. 71. *Protoceratium areolatum*, sp. nov., sinistro-ventral view. × 935.

Fig. 72. *Phalacroma reticulata*, sp. nov., dextral face. × 450.

Fig. 73. *Phalacroma striata*, sp. nov., sinistral face. × 337.

Fig. 74. *Dinophysis triacantha*, sp. nov., dextral face. × 700.

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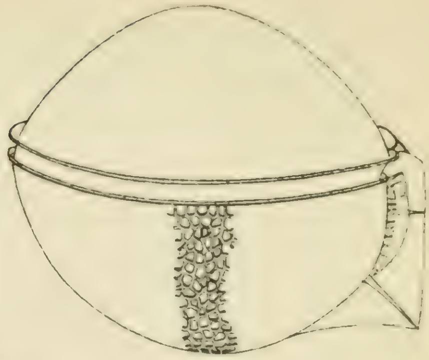

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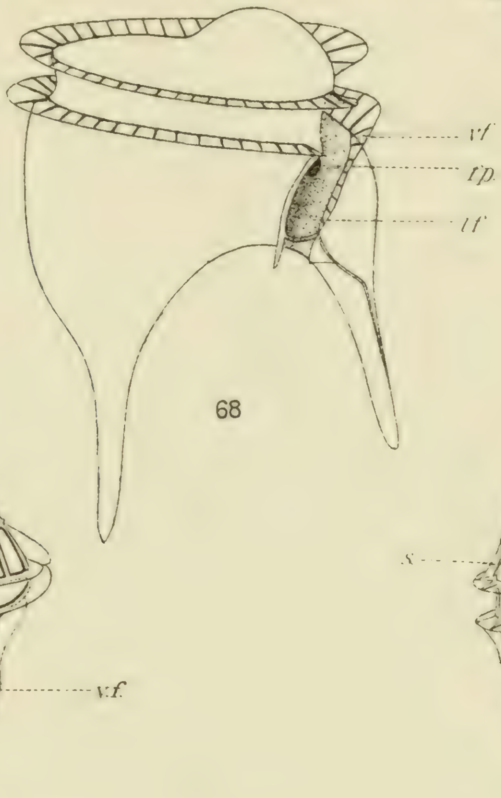

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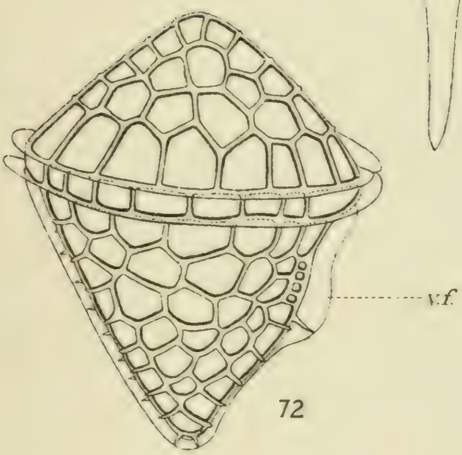

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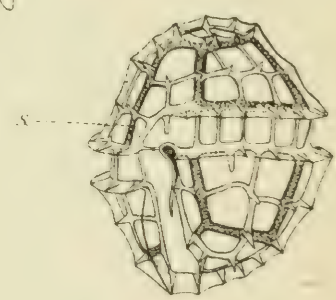

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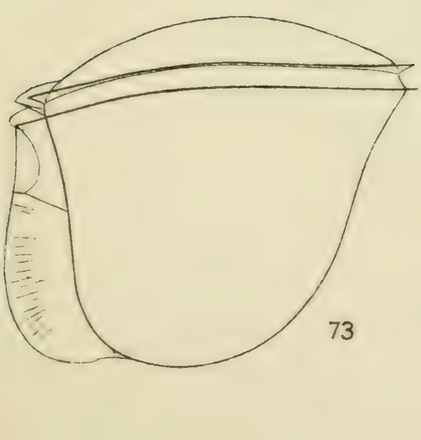

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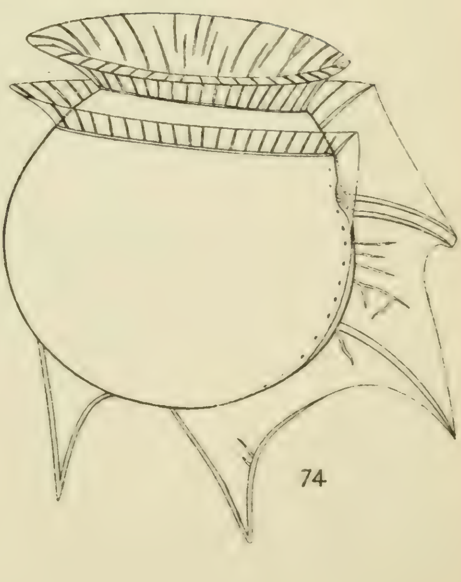

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PLATE 13.

Fig. 75. *Amphisolenia quinquecauda*, sp. nov., dextral face. × 100.
Fig. 76. *Amphisolenia asymmetrica*, sp. nov., dextral face. × 100.
Fig. 77. *Amphisolenia projecta*, sp. nov., dextral face. × 450. From life.
Fig. 78. *Amphisolenia extensa*, sp. nov., dextral face. × 100.
Fig. 79. *Amphisolenia brevicauda*, sp. nov., dextral face. × 450.
Fig. 80. *Amphisolenia laticincta*, sp. nov., dextral face. × 450.
Fig. 81. *Amphisolenia schroederi*, sp. nov., dextral face. × 300.
Fig. 82. *Amphisolenia dolichocephalica*, sp. nov., dextral face. × 100.

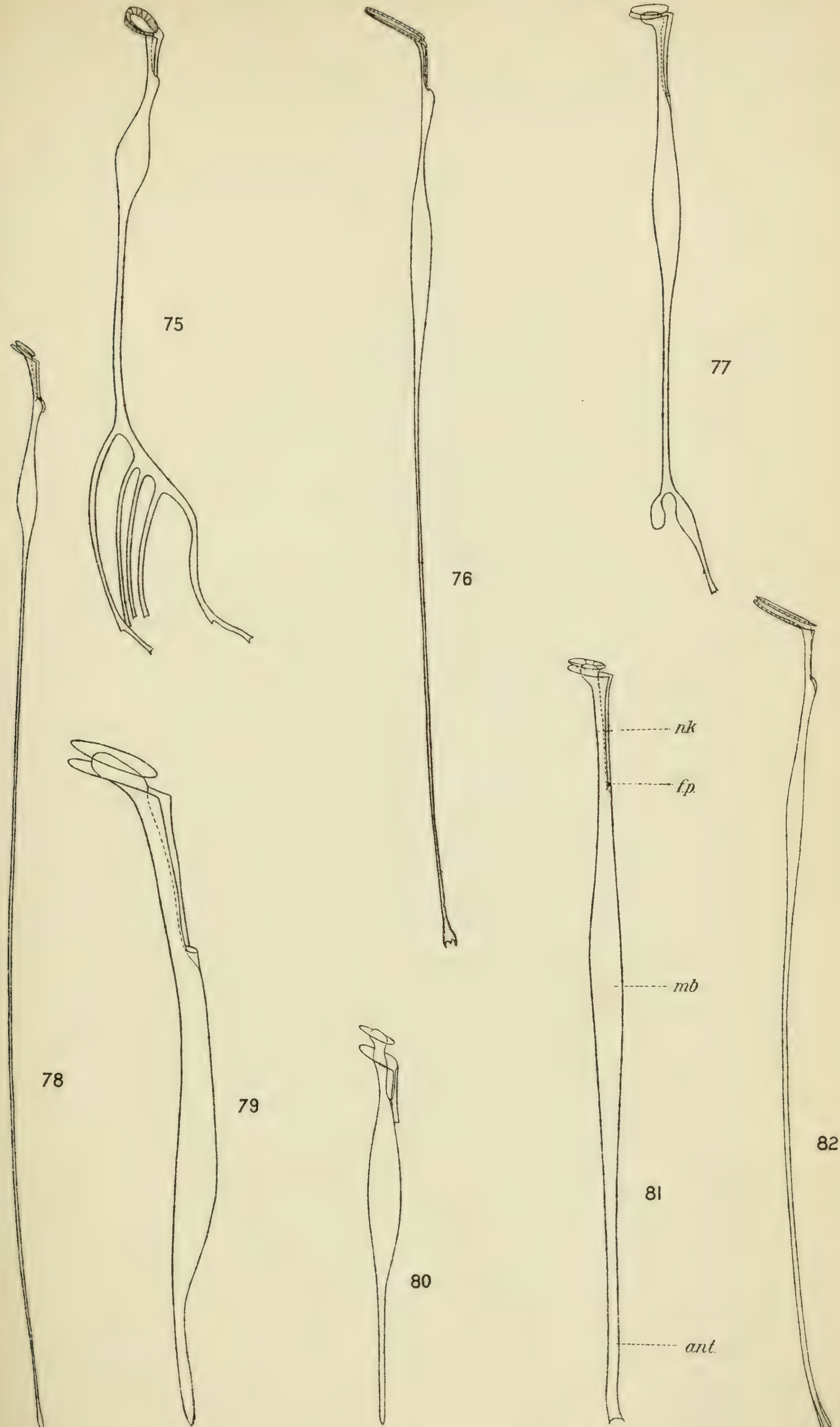

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PLATE 14.

Fig. 83. *Amphisolenia rectangulata,* sp. nov., dextral face. $\times$ 200.
Fig. 84. *Amphisolenia palaeotheroides,* sp. nov., dextral face. $\times$ 208.
Fig. 85. *Amphisolenia bispinosa,* sp. nov., dextral face. $\times$ 200.
Fig. 86. *Amphisolenia quadrispina,* sp. nov., dextral face. $\times$ 200.
Fig. 87. *Amphisolenia curvata,* sp. nov., dextral face. $\times$ 200.
Fig. 88. *Amphisolenia lemmermanni,* sp. nov., dextral face. $\times$ 200.
Fig. 89. Same, ventral view of antapex. $\times$ 200.
Fig. 90. *Amphisolenia clavipes,* sp. nov., ventral view. $\times$ 450.

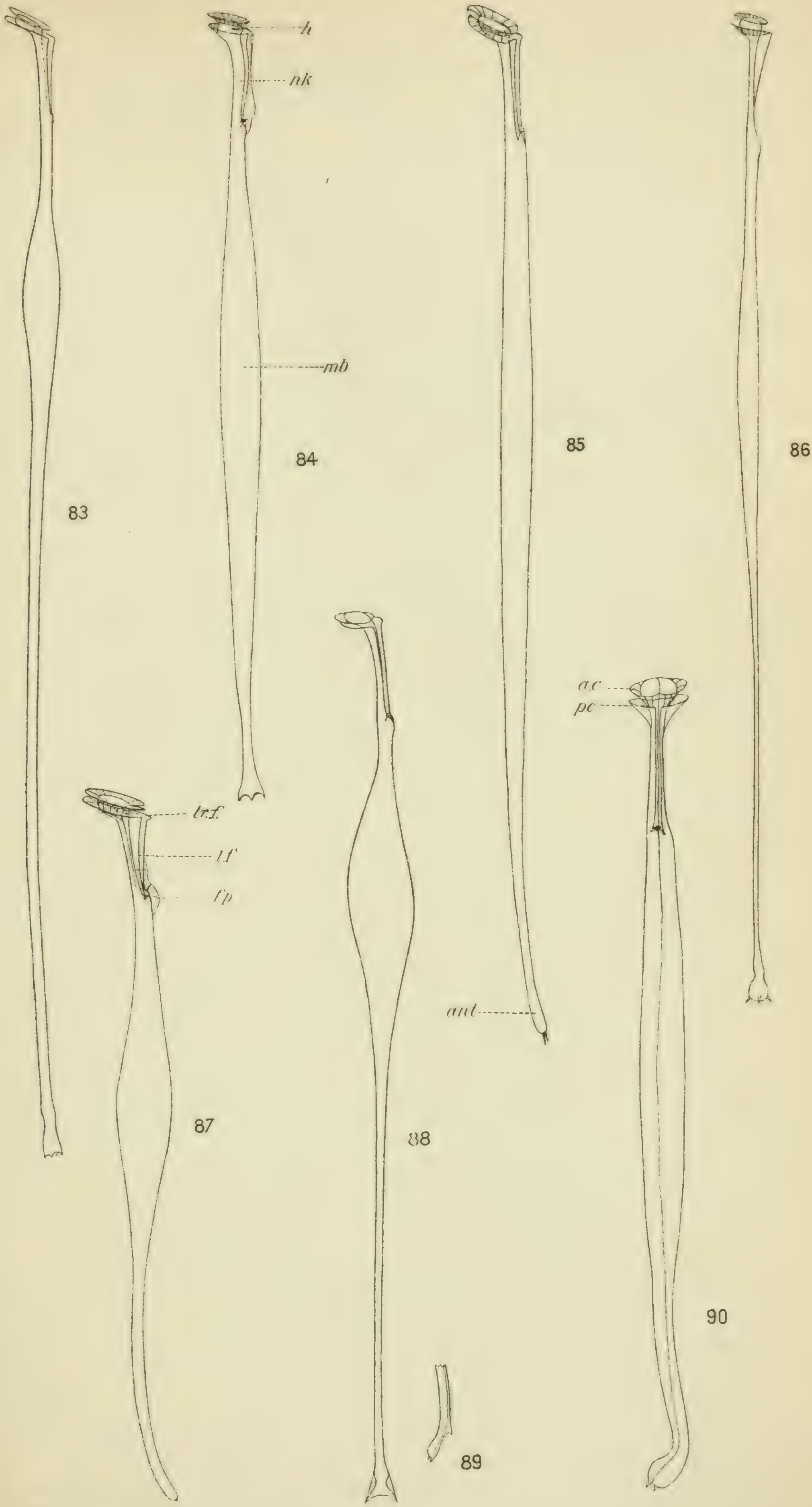

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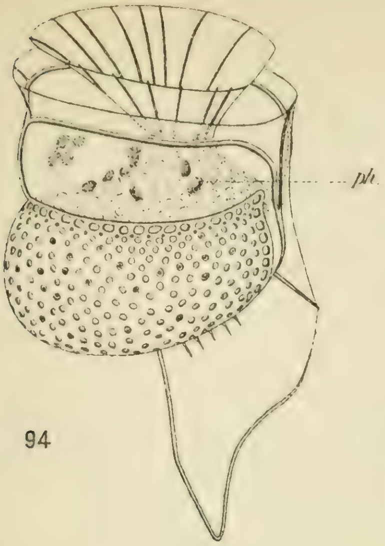
PLATE 15.

Fig. 91. *Histioneis josephinae*, sp. nov., dextral face. × 840.
Fig. 92. *Ornithocercus carolinae*, sp. nov., dextral face. × 535.
Fig. 93. *Ornithocercus serratus*, sp. nov., dextral face. × 450.
Fig. 94. *Histioneis paulseni*, sp. nov., dextral face. × 840.
Fig. 95. *Histioneis reticulata*, sp. nov., dextral face. × 840.



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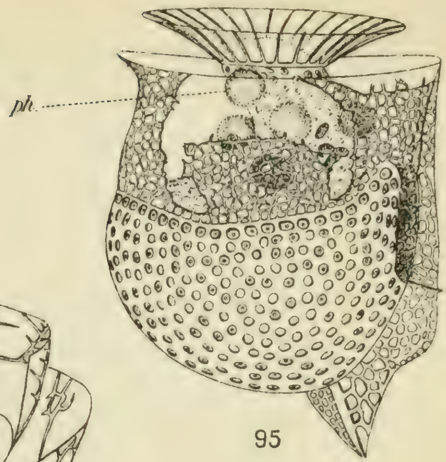

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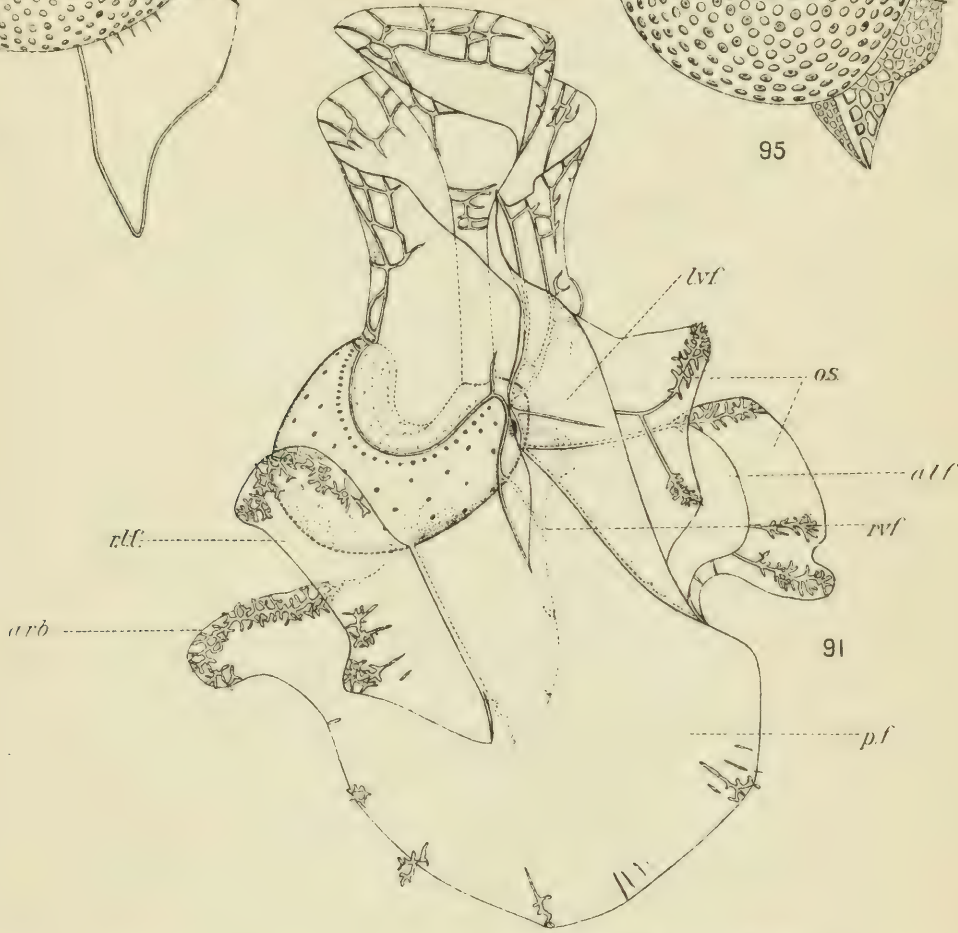

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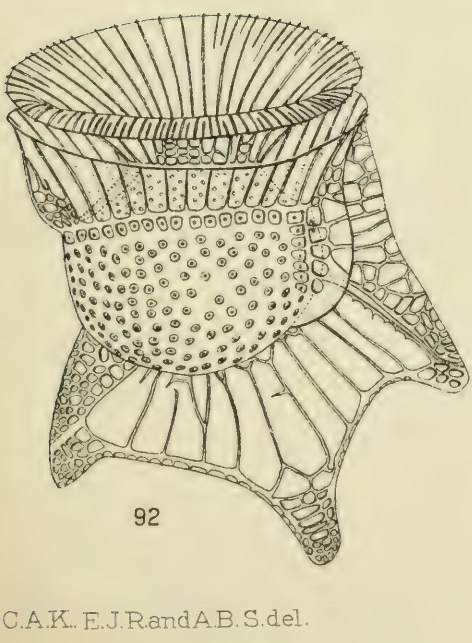

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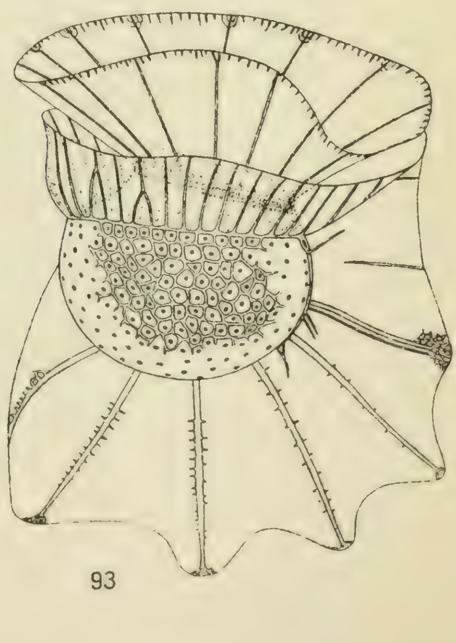

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PLATE 16.

Fig. 96. *Histioneis navicula*, sp. nov., dextral face. × 840.
Fig. 97. *Histioneis garretti*, sp. nov., dextral face. × 840.
Fig. 98. *Histioneis carinata*, sp. nov., dextral face. × 840.
Fig. 99. *Histioneis pulchra*, sp. nov., dextral face. × 840.
Fig. 100. *Histioneis longicollis*, sp. nov., dextral face. × 840.

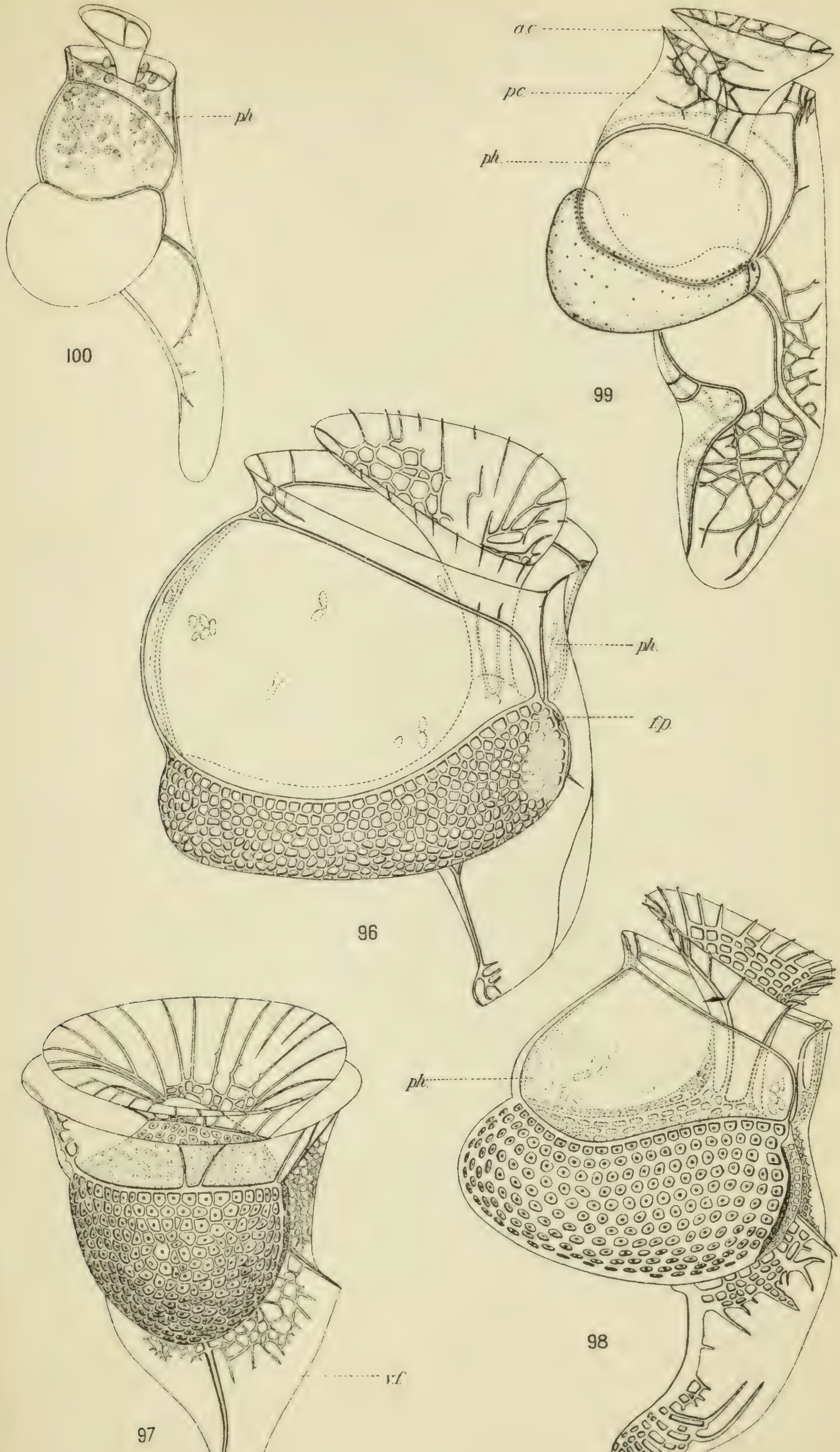

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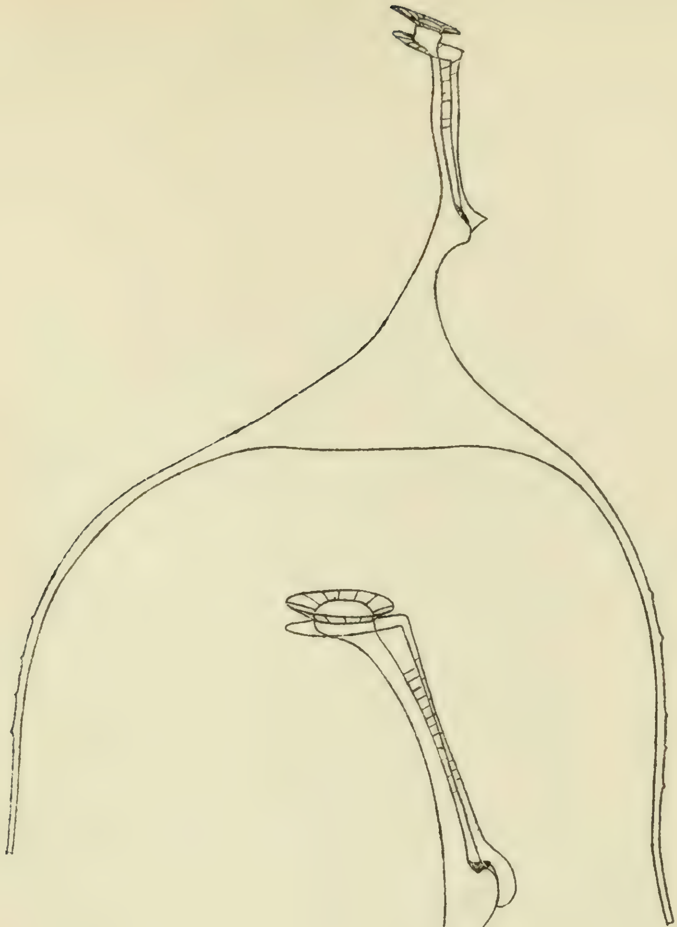
PLATE 17.

Fig. 101. *Triposolenia longicornis*, sp. nov., view of right face. × 505.
Fig. 102. *Triposolenia fatula*, sp. nov., view of right face. × 505.



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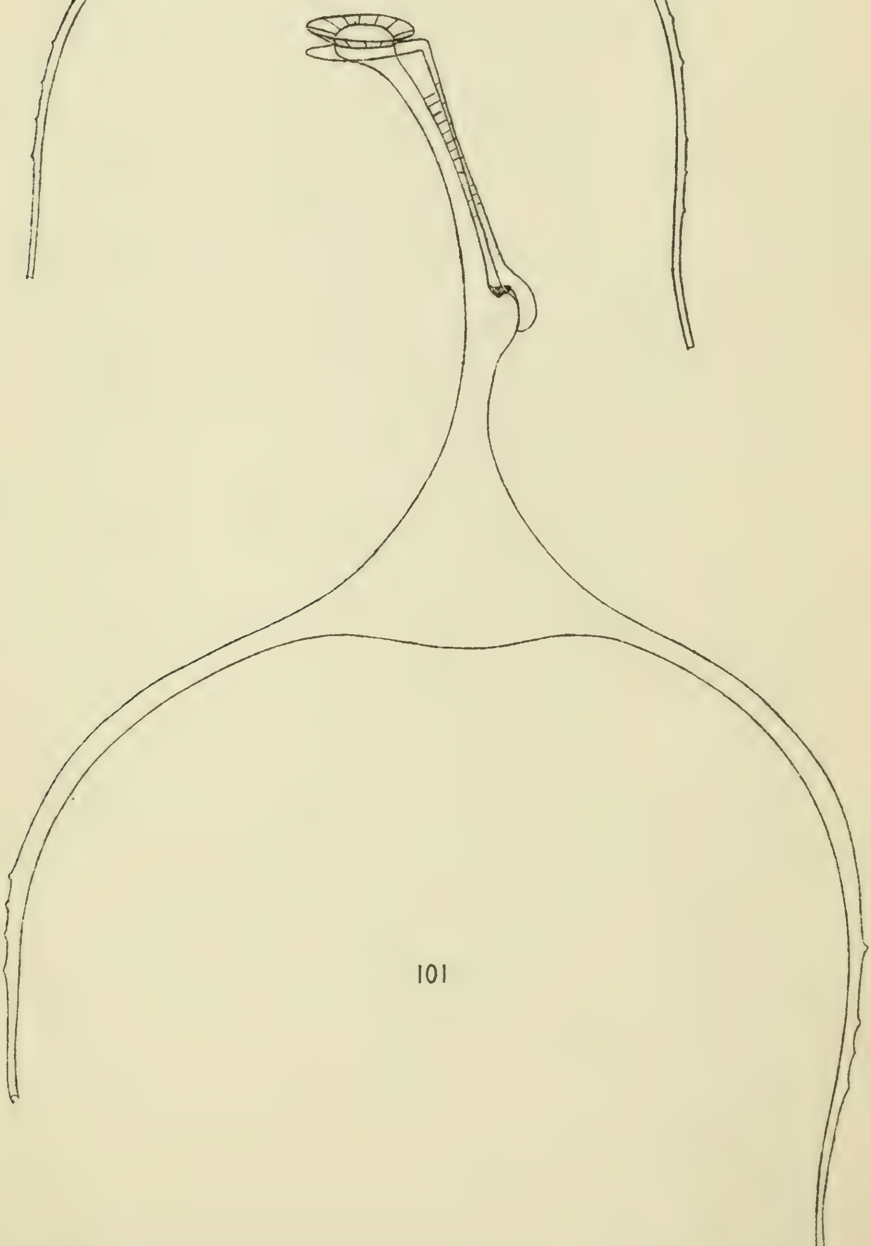

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PLATE 18.

Map showing position of the stations occupied by the "Albatross" during the cruise in the Eastern Pacific in 1904–1905.

B. Meisel Lith.

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Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. L. No. 7.

MYLOSTOMID DENTITION.

By C. R. Eastman.

With One Plate.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

February, 1907.

No. 7.—*Mylostomid Dentition.* By C. R. Eastman.

The reconstruction of the Mylostomid type of dentition acquires significance through its relevancy to the larger question of the affinities of Arthrodires. Nature has not disclosed to us by direct evidence the manner in which upper and lower dental plates of Mylostomids functioned against one another during life. The disposition of the various parts must therefore be determined by indirect means, such as by observing evidence of co-adaptation, mutual contact and wear, and, so far as may be, through analogy with related forms. In reality the problem is a simple one, devoid of mystery and intricacy, and requiring little mechanical ingenuity for its solution and complete verification. Of trivial intrinsic importance, its solution promises enlightenment as to the relations of the perplexing group of Arthrodires. A matter of minor interest in itself, it determines consequences of real magnitude, and hence is worthy of thoughtful consideration. It is proposed in the following pages to examine into the general nature of the problem, the different solutions that have been proposed for it, and some of the consequences depending thereon.

The limiting conditions of the problem may be stated first. Mylostomids are known upon the evidence of two fairly well-preserved skeletons to be Arthrodiran fishes essentially like Dinichthys, except that their dentition is adapted for crushing instead of cutting. The two specimens referred to are the only ones thus far discovered which present us with the disarranged but nearly complete dentition of single individuals. The fact that in each case the dental elements are known positively to have belonged to a single individual not only facilitates their reconstruction, but furnishes a scale of relative proportions which may be presumed to hold constant throughout the species. Thus provided with a standard of comparison, we may select from a sufficiently large assortment of detached plates the necessary components of a complete dentition, all of whose parts shall be proportionate with respect to one another, and shall have precisely the same conformation as those known to have been associated in a single mouth. Or, given a detached mandible of the same configuration as those found in natural assemblage with other parts,

the size of the upper dental plates which must have accompanied it during life can be predicted with entire accuracy.

Experience having shown that all of the dissociated dental elements now known, upper and lower, exhibit among themselves practically uniform dimensions and uniform conformation, one is entitled to conclude therefrom that they represent average-sized individuals, and that the elements were arranged after an invariable pattern. For, supposing their disposition to have been inconstant, we should be at a loss to account for their marked regularity of form and proportion, and similar indications of wear. Hence any theoretical reconstruction of the dentition, whether based upon detached specimens or upon the evidence of naturally associated parts, must satisfy the test of totality. It must apply universally, not only to such plates as are known to have belonged to a single individual, but to all those that have been found in the detached condition as well; it must be compatible with all their essential features, and be negatived by none of them.

It may be that only one, or more than one theoretical reconstruction of the dentition is competent to explain all the observed facts. As between two rival hypotheses, that one may be regarded as the more plausible which is mechanically simple, free from anomalous suppositions, and in harmony with analogy. An hypothesis which is mechanically complicated, presupposes anomalous conditions, and violates analogy, is less worthy of credence. For in so far as it depends upon the assumption of the unique, of something for which nature affords no parallel, it becomes improbable; and the improbable is always to be distrusted. Speaking broadly, any hypothesis whatsoever has the elements of trustworthiness, provided it can be shown to agree with a number of diverse facts. The greater number of diverse facts with which it agrees, the more completely can it be verified. When many circumstances point toward a single conclusion, the chances of that conclusion being correct are enormously increased with each additional favoring circumstance. They might even be supposed to increase in geometrical rather than in arithmetical ratio. Finally, an hypothesis that is found to agree entirely with observed facts cannot but be believed to be true. It will be instructive to inquire how far either of the two extant interpretations of Mylostomid dentition are in accordance with observed facts.

Newberry's Views. — Our earliest information regarding the Mylostomid type of dentition is due to the zeal and acumen of Professor J. S. Newberry, who described the constituent elements of the type species,

M. variabile, and also founded a second species, *M. terrelli*, upon the evidence of a solitary mandibular plate. He noted the general correspondence between the Mylostomid and Dinichthyid type of mandible, and observed that the former occurred together with two distinct varieties of "flattened tabular dental plates . . . exhibiting the same microscopic structure," which were properly referred to the upper dentition of the same species. He made no effectual attempt, however, to work out the arrangement of the pavement teeth, merely observing that their "sides are straight or bevelled, apparently for co-adaptation, and by this character favor the conclusion that the dentition consisted of many pairs of plates, constituting a tesselated pavement; the crowns of the teeth below being convex, those above concave."[1] The front margin of the mandibular plates was also considered by this author to show evidence of co-adaptation with other dental structures; and in order to satisfy the hypothetical requirements thus created, a pair of "premandibular" elements was not only postulated by him, but two specimens figured in his monograph[2] were actually referred to this position, albeit with some reservation. We will return later on to a discussion of these so-called "premandibular" plates, under a separate heading.

Newberry's investigations of Mylostoma served to acquaint us in all, as he supposed, with four pairs of dental structure, one of which was correctly identified as belonging to the lower, and two to the upper jaw, while the position of the fourth was acknowledged to be uncertain. His reasons for referring these various pairs to a single species are that they were found to occur together, and to exhibit identical structure and surface markings. The circumstances of their discovery are not related in detail, but it is significant that all specimens of Mylostoma known to Newberry, excepting the type of *M. terrelli*, were obtained by one collector from a single horizon and locality, namely, the Cleveland shale of Sheffield, Ohio. Newberry's suggestion that several pairs of plates besides these four took part in the complete dentition, and that the upper series formed a tesselated pavement, shows that he had only a vague and illusory idea of their arrangement. He even confused the right and left mandibular plates. His work was essentially that of a pioneer, and as such is praiseworthy, although necessarily imperfect. It was at Dr. Theodore Gill's suggestion that he undertook the first comparisons between the dentition of Arthrodires and Dipnoans, the

[1] Newberry, J. S., The Palaeozoic Fishes of North America. Monogr. U. S. G. S., **16** (1889), p. 166.

[2] *Ibid.*, p. 161, 165, Plate **16**, Fig. 4.

former's ideas as to the relations of Homosteus having been published as early as 1872.

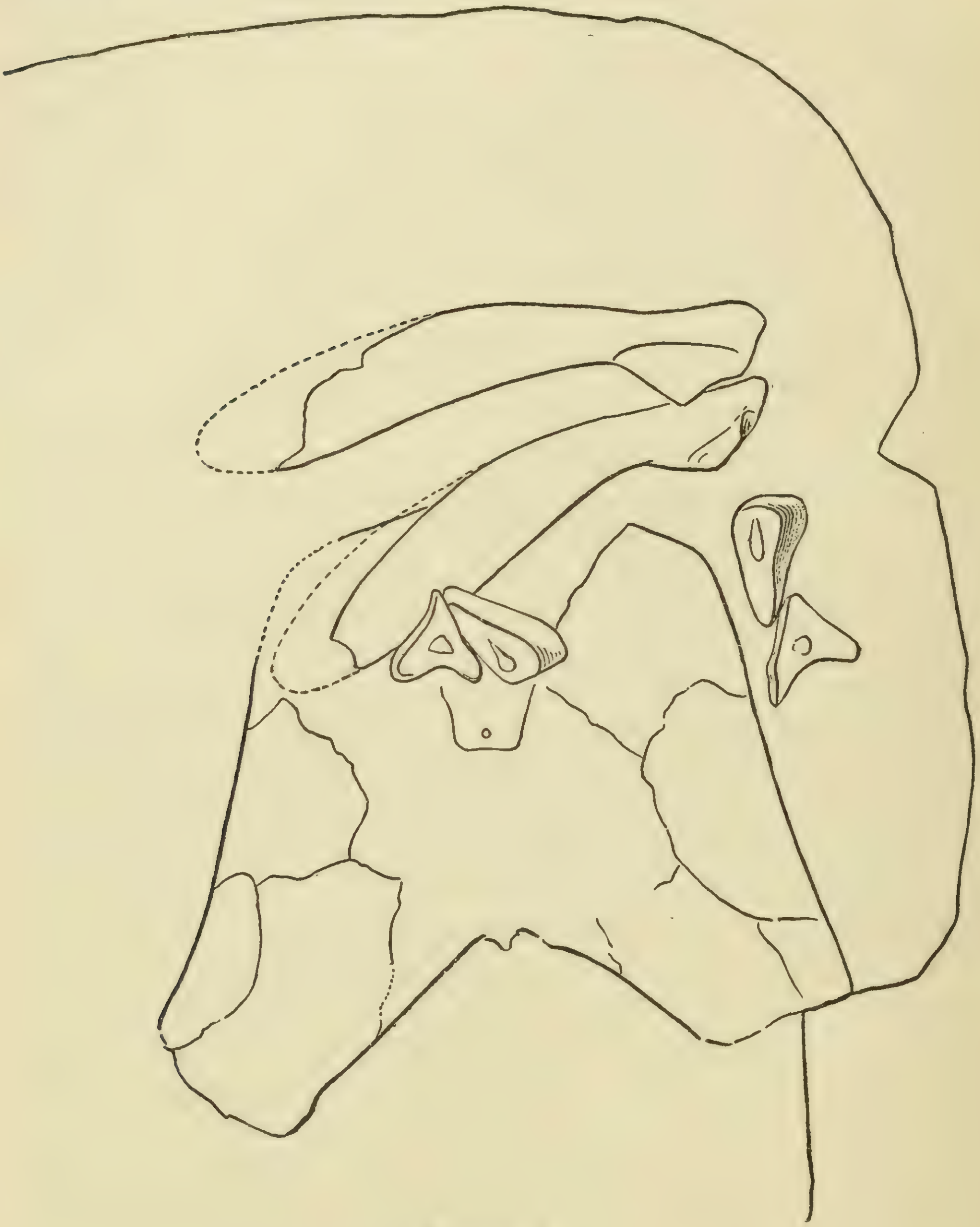

FIGURE *A*.

Outline sketch showing the position in which the constituent parts of the dentition were embedded with respect to the headshield in the block of shale containing the single individual of *Mylostoma variabile* juv. Museum Comp. Zoöl. (Cat. 1490); Amer. Mus. Nat. Hist. (Cat. 7526). × ⅓. (After Dean.)

DEAN'S INTERPRETATION. — To Professor Bashford Dean belongs the credit of having attempted the first serious and thorough-going restoration

of the dental apparatus of Mylostoma, his interest in the problem having been aroused by the discovery of a well-preserved skeleton of *M. variabile*, the various parts of which obviously belonged to a single individual. This specimen presented for examination the flattened headshield, some half-dozen plates of the abdominal armor, both mandibles, and two pairs of crushing dental plates, all embedded in close proximity to one another in a single block of shale. There were no indications, however, of the presence of a fourth pair of dental elements, corresponding to the so-called "premandibular teeth" of Newberry, and these latter do not enter into Dean's reconstruction.

As will be seen from Figure *A*, which is copied from Dean, the two mandibular rami were found lying nearly parallel to each other in close

Figure *B*.

Restoration of the complete dentition of Mylostoma, based upon the single individual of *M. variabile* shown in Figure *A*. The length of the mandibular dental plate is slightly exaggerated in the outline here shown. $\times \frac{1}{3}$. (After Dean).

proximity to the headshield, and at no great distance from the separated halves of the palatal dentition. The two plates interpreted by Dean as belonging to the right-hand side of the palate are in direct apposition with each other, their contact edges being in remarkably close adjustment. These circumstances, the fact that the two right-hand palatal plates remain together while the corresponding left-hand plates have become separated, and the fact that their opposed edges show almost perfect co-adaptation, are held by Dean to point irresistibly to the conclusion that the elements in question have preserved their natural arrangement with respect to each other.[1] It is not demonstrated by the author, but merely considered as extremely probable that

[1] Dean, B., Palaeontological Notes. Mem. N. Y. Acad. Sci., 1901, 2, p. 104.

the relations of these plates have not been disturbed; and this inference is made by him the determining factor of his restoration (Fig. *B*), the starting-point of his theory of rotary jaw-movements, and the key-note to a novel interpretation of Arthrodires. One perceives, accordingly, that extremely weighty conclusions depend upon Dean's initial assumption, the truth or error of which requires to be demonstrated. Sufficient reason for distrusting its correctness is found in the improbability of the conclusions resting upon it, the more important of which are contrary to analogy. We may therefore profitably inquire into the reasonableness of the author's initial assumption, and ascertain, if possible, to what extent it invites confidence.

The one clearly demonstrable feature of the single specimen of Mylostoma studied by Dean is that the right and left halves of the palatal dentition have become separated; and that, although the components of either half remain in association, they are dissimilarly oriented. This state of affairs permits of three possible explanations, which may be stated as follows: —

1. The two right-hand palatal plates have preserved their natural orientation with respect to each other, and the two left-hand plates alone have become disarranged.

2. The two left-hand palatal plates retain their natural orientation with respect to each other, and the two right-hand plates have become disarranged.

3. The components of both halves of the palatal dentition have become turned about, so that none of them any longer occupy their original position with respect to one another.

Circumstantial evidence is our only resource for determining which one of these conclusions is correct. A strong point in favor of the first is the neat adjustment between the contact edges of the plates, which are preserved in direct apposition. At the same time, the close fit observed between the two nearly straight edges cannot be regarded as really decisive proof, owing to the possibility of its being the result of chance. The two right-hand palatal plates may or may not be retained in natural position; the only test that can be absolutely relied on for determining their arrangement, the real *experimentum crucis*, consists in bringing the functional surfaces of the two upper dental plates into harmonious adjustment with the mandibular, so that a number of diverse features of both upper and lower dental plates shall stand in reciprocal relations. When tubercles are found to fit into grooves or pits, eminences into depressions, and marks of wear to coin-

cide at all points we have evidently found the true arrangement; since only in this manner could the parts have interacted during life. Application of this test to the single individual of Mylostoma we are considering, and also to an extended series of detached plates, shows that Dean's reconstruction fails to explain all the facts, and only explains some of them by positing anomalous, and *pro tanto* improbable conditions. In a word, the arrangement is unable to satisfy the test of totality. It is, therefore, inadequate, and the initial assumption upon which it is based must be regarded as erroneous.

The principal objections to Dean's reconstruction may be thus summarized: —

1. The proposed arrangement necessitates the assumption of jaw-movements in Arthrodires which are unparalleled amongst Chordates.

2. No close analogy is suggested by this arrangement with the dentition of related forms.

3. Some conspicuous indications of wear, the position of which is constant in all plates thus far brought to light, are wholly unaccounted for by this arrangement.

4. According to this arrangement, the marginal contours of upper and lower dental plates do not coincide. A considerable portion of the oral surface of all the plates is left uncovered when the jaws are closed, even including areas which show indications of wear.

5. One of the two palatal plates found lying in apposition in the nearly complete example of Mylostoma (the one called "premaxillary" by Dean) is observed to present a worn surface immediately adjoining the contact margin with the so-called "maxillary" element. The latter, however, is unworn along the contact margin, but is raised there into a prominent ridge. Supposing these plates to have been naturally in contact, they must needs exhibit similar evidence of attrition along their common margin; since they do not, they must have been arranged in some other manner.

6. The only strictly linear margins of any of the plates are not in contact with each other, nor are the members of either pair in direct apposition along the median line.

Eastman's Interpretation. — The arrangement proposed by the present writer was first established upon the evidence of detached plates, which were fitted together conformably to the marginal contours of upper and lower dentition, and in such manner as to account at all points for reciprocal marks of wear. Its efficiency was afterwards tested by applying the same arrangement to the single example of Mylostoma

studied by Dean. The two left-hand palatal plates being removable from the specimen, they were rearranged in the prescribed manner, and their oral surfaces fitted against the mandibular dental plate. The experiment was also repeated with the aid of plaster casts of the two right-hand palatal plates, which were not removable, and in both cases the new arrangement was found competent to explain all the facts in thoroughly satisfactory manner. Its effectiveness will be readily understood from inspection of Figure *C*, drawn from the original specimens, and from the following discussion of details.

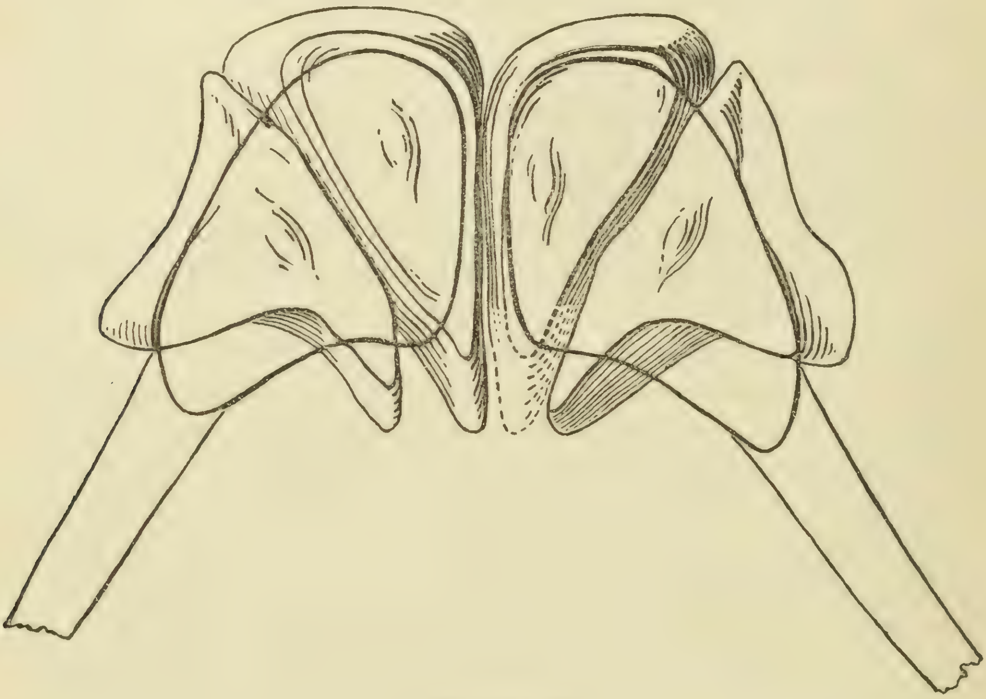

Figure *C*.

Proposed reconstruction of Mylostomid dentition, based upon the originals shown in preceding text-figures. × ½.

We have already stated that the juxtaposition of dental plates in the nearly complete example of Mylostoma is such as to admit of three possible conclusions, only one of which can be true. The new arrangement proceeds to test, and afterwards to affirm the correctness of the second of these conclusions, which are here restated for sake of clearness.

1. The two right-hand palatal plates are retained in their natural position with respect to each other. (Disproved.)

2. The two left-hand palatal plates are naturally oriented with re-

spect to each other, and the two right-hand plates have become disarranged.

3. None of the palatal plates retain their natural position with respect to one another.

By orienting the two right-hand plates in corresponding fashion to the two left-hand, and then approximating the disjoined halves of the dentition, a symmetrical pattern is formed, such as is shown in Figure *C*, and repeated in Plate 1. An obvious feature of this arrangement is that the only elongate linear margin of any of the plates is directed parallel to the median line, and it is along this line that the paired elements having a single straight margin are mutually in contact. The evidence of co-adaptation presented in this respect is sufficiently striking, and it will be at once recalled that analogous conditions are found in various types of Dipnoan dentition.

We have now to apply the most crucial test open to us with the means at our command. It consists in bringing the functional surfaces of mandibular and palatal plates together and observing the extent of their mutual correspondence. Immediately this is done it becomes patent that a close coincidence exists between the contour lines of upper and lower dentition; the jaw-parts fit together as accurately as may be when the mouth is closed, and their impact is exactly such as is capable of producing the observed marks of wear. The triturating areas that were left uncovered in the preceding restoration (Fig. *B*) are now brought into much closer adjustment above and below, the contrast presented by Figure *C* in this respect being self-evident. It thus appears that the fourth in the list of objections to Dean's arrangement (*v.* p. 217) is inapplicable in the present instance.

Amongst other constant features of the anterior pair of palatal plates are to be noted the following: The linear inner (ental) margin is elevated into a distinct ridge, which increases in height and breadth in the vicinity of the antero-internal angle of the plate, where it shows evidence of attrition. The marks of wear extend not only along the side of this ridge, but also over the concave surface of the plate immediately adjacent to it. The summit of the elongate, mesially placed tubercle is worn, and the sunken area in advance of this, extending as far as the antero-external angle is the most conspicuously worn of all. This concavity is particularly well displayed in the detached specimens figured by the writer in Bulletin Mus. Comp. Zoöl., **50**, no. 1, Plate 1, Figures 2, 3. Now, the significance of all these features becomes apparent when the functional surface of the plate in question is applied

against the mandibular in the manner already described. On bringing the two surfaces together, all marks of wear observable in the anterior palatal plate are seen to coincide with similar worn areas of the opposing plate, thus fully disclosing their mutual relations.

The ental margin of the mandibular plate fits just within and against the side of the ental ridge of the palatal plate, and closes against the thickest and highest portion of the ridge near the antero-internal angle, where both plates are deeply worn. The ectal rim of the mandible fits accurately into the broad and deeply worn concavity of the palatal plate, the surface of the one being a faithful replica of the other, and the relations between them being comparable to those of a die-stamp. The extremely prominent bifid eminence which rises midway the length of the mandibular plate along its ental margin functions within the depressed posterior surface of the palatal, and the longitudinal cleft by which the eminence is divided embraces the elongate, mesially placed, and longitudinally directed tubercle of the palatal plate, whose summit fits into a shallow groove of the mandibular plate. Thus an inter-relationship between all the parts is demonstrable, which must faithfully indicate their natural arrangement, since no other is capable of producing the observed effects. Having ascertained the relations of the anterior palatal plates, it is an easy task to bring the hinder one into adjustment with it and with the remaining portion of the lower dentition.

The posterior palatal plate may be described as approximately cordiform, or subtriangular. Not more than two of its borders are straight or slightly concave, the third being profoundly indented, and for that reason incapable of direct contact with the preceding element. The contact margin must therefore have been formed by one or the other of the nearly linear sides, and by experimenting with them in connection with the two plates whose relations have already been determined, it is readily perceived which one of these sides permits of harmonious adjustment. The pointed anterior extremity of the plate we are now considering adapts itself regularly to the outer contour line of the mandible; its worn centrally placed tubercle fits into a depression of the lower plate; and its marginally situated tubercle closes just back of the elevated prominence of the mandibular plate, playing into a declivity that occurs on the inner face of the latter. The surface irregularities of both plates, together with all their indications of wear, are thus fully accounted for by this arrangement. Noteworthy also is the fact that precisely similar relations obtain in Dinomylostoma, where the orien-

tation of the posterior palatal plates is determined with absolute accuracy. Another point confirmatory of the new arrangement is that in the nearly complete example of Mylostoma (Fig. *A*), the posterior pair of palatal plates occurs symmetrically oriented with reference to the median line. From this it is evident that the only one of the four palatal plates whose position has been disturbed, aside from lateral displacement, is the right anterior.

The present reconstruction of the palatal dentition of Mylostoma thus provides a consistent explanation of all observed facts, and is at variance with none of them. It is free from theoretical objections, is in harmony with analogy, both with Dinichthys and Ceratodonts, and is applicable to all specimens thus far discovered, whether found in the detached or associated condition. Its correctness may therefore be regarded as definitely proved. Up to the present point the discussion has been purposely restricted to the palatal and mandibular dental plates.

Concerning those structures interpreted by Newberry as "premandibular," and by the present writer in earlier papers as "vomerine" teeth, it is now necessary to speak more particularly. I purpose showing that the three known specimens which have received this designation do not belong to the type species of Mylostoma, but to a smaller, very distinct form, presently to be described under the name *M. newberryi*. Moreover, the specimens in question are no longer interpreted as vomerine, but as mandibular plates which have become accidentally dissociated from their supporting splenials, or from the greater part of these bones. The presence of vomerine teeth in Mylostoma is therefore not yet demonstrable by any positive evidence that has come to light, although their potential occurrence is to be inferred from analogy with Dinomylostoma and Coccosteans generally.

Indications of a New Species of Mylostoma. — As already stated, Newberry was of the opinion that the lower dentition of Mylostoma consisted of at least two pairs of dental plates, mandibular and "premandibular," opposed to which in the upper jaw was a "tesselated pavement consisting of many pairs of plates." Bashford Dean was enabled to show that the upper pavement dentition was made up of two pairs of plates only, against which functioned the single mandibular pair. In the nearly complete example of *M. variabile* studied by this author no trace was observed of yet another fourth pair of dental structures, corresponding to those named premandibular by Newberry, and vomerine by the present writer. The originals of Newberry's figures do not enter

into Dean's restoration of the Mylostomid dentition, nor is their existence mentioned. As a matter of fact, the actual specimens had been lost sight of for many years, and in the absence of satisfactory illustrations it was difficult to hazard a conjecture as to their nature. Without having studied the originals, no one could have concluded that they had suffered such injury as to obscure their real nature, nor could any good reason be assigned for excluding them from association with the type species of Mylostoma.

By a fortunate chance the original pair of Newberry's so-called "premandibular teeth" have been preserved intact in the Museum of Oberlin College, where they were overlooked until recently. Being recognized by Dr. Hussakof, after searching various collections, they were loaned to him and subsequently placed in the hands of the present writer for purpose of further study and description. Grateful acknowledgments are hereby rendered to the writer's colleagues in New York and Oberlin for having thus provided an opportunity for the following observations.

Comparison of the original pair of dental elements figured in Plate **16**, Figure 4, of Newberry's Monograph with the lower dental plates of Mylostoma, especially those of the single individual of *M. variabile* described by Dean, leaves no room for doubt that they are of similar nature. We have not to do with integral paired structures representing a distinct element, but with a fractured pair of mandibles belonging to a new species of Mylostoma. The inferior aspect in particular of Newberry's originals displays the usual conformation of grooves, ridges, and hollows with which we are familiar in Mylostomid mandibles. One of these grooves is extremely characteristic of the Arthrodiran type of mandible, always occupying the same position, and from its similarity to a corresponding groove in modern Dipneumoni, has been interpreted as serving to lodge remnants of the Meckelian cartilage. The line of fracture along which the posterior shaft of the splenial has been broken off is irregular, even ragged in places, and so obviously the result of injury that it is surprising Newberry should not have noticed it. Curiously enough, in the case of the solitary known specimen agreeing with the typical pair, the same which we have previously called "vomerine," signs of injury are scarcely to be perceived, and would seem to have become almost wholly obliterated by post-mortem attrition. Yet it follows by implication that the Cambridge specimen has likewise suffered the loss of the supporting splenial.

There can be no question that the Oberlin pair of mandibular plates

belonged to a single individual. This is shown by their almost perfect symmetry, similar texture, equal extent of wear, and especially by the evidence of co-adaptation along their linear inner margins, where they were in contact along the median line. The indications of a rigid cartilaginous union at the symphysis are of an even more positive character than in Ptyctodonts, for in these plates the contact line is more extended, and the adjustment along the vertical inner face more accurate. On bringing these surfaces into adjustment, it is easy to see from the alignment of the splenial portions that the angle subtended by the mandibular rami must have been very narrow. The pointed form of the plates in front leads also to the conclusion that the head was sharp-snouted, slender, and elongate, indicating a creature adapted for rapid motion, and possibly one having an eel-like form of body.

A marked feature of the mandibular plates as compared with those of the type species of Mylostoma is the narrowness of their functional surface, with tapering forward extremities, a character by which the new form is readily distinguished from all other Mylostomids. The triturating surface is moderately convex, and displays the usual tubercle along the inner margin, although this is less elevated than in other species, and is more distinctly separated from the posterior portion of the plate by a deep sinus. This is the concavity referred to in Newberry's description, where it is suggested that the posterior margin of the "premandibular" plates is "obliquely notched, apparently to receive the obtuse points of the larger teeth." In addition to the main eminence along the inner margin, faint indications are visible in the Cambridge specimen of two or three rows of smaller tubercles, radiating outwards in a manner strikingly suggestive of Ctenodipterine teeth. Similar markings were no doubt present in the Oberlin examples as well, but have become obliterated by wear. Their larger size and more worn condition suggest that they pertained to an older individual than that represented by the Cambridge specimen (M. C. Z., Cat. no. 1439). The form of all three strongly recalls Ctenodipterine conditions, and it is probable that the resemblance extended to the upper dental plates as well. They were no doubt attenuated anteriorly in corresponding fashion with the mandibular plates, their oral surfaces were regularly concave and very possibly tuberculated, and it would not be at all surprising if the two pairs of upper dental plates common to other Mylostomids were in this species fused into one. This would give rise to a compact triangular-shaped plate, closely paralleling those of typical Dipnoans.

The new species may appropriately be named in honor of the memory

of Professor Newberry. Its principal characters are summed up in the following definition.

Mylostoma newberryi, sp. nov.

Fig. D.

1889. *Mylostoma variabilis* Newberry, Mon. U. S. Geol. Surv. **16**, p. 165, plate **16**, fig. 4 (*non* figs. 1–3).

1906. *Mylostoma variabile* Eastman, Bull. Mus. Com. Zoöl., **50**, p. 22, plate **1**, fig. 7 (*non* figs. 1–5, 8–9).

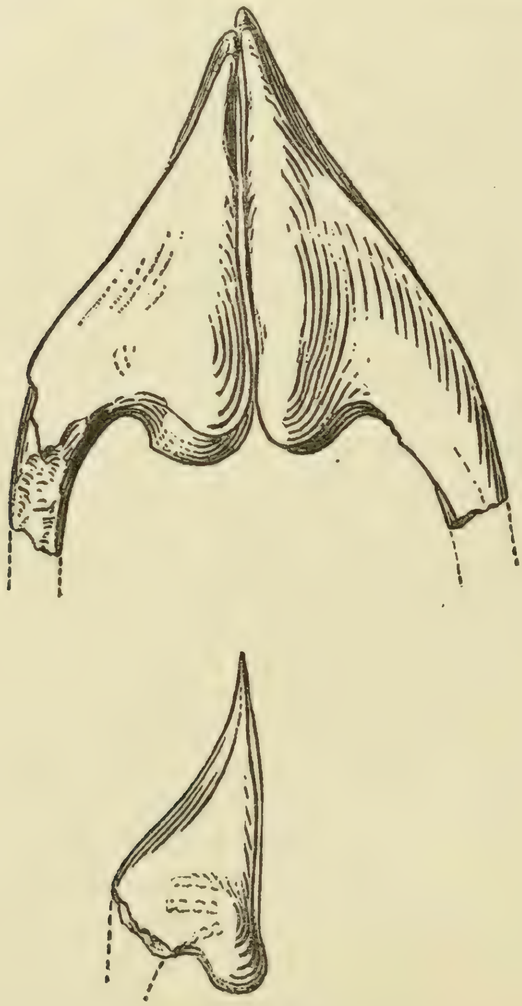

FIGURE *D*.

Mylostoma newberryi, sp. nov. Cleveland shale; near Sheffield, Ohio. *Above*, the original pair of Newberry's so-called "premandibular teeth," here interpreted as mandibular (Oberlin Museum Cat. 1302). *Below*, a smaller left mandibular plate (Museum of Comparative Zoölogy Cat. 1439). × 1/1.

An imperfectly known species, established upon the evidence of mandibular dental plates which have become accidentally dissociated from their supporting

splenials. Functional surface moderately convex, of narrow, subtriangular outline, tapering and acutely pointed in front, with elongated linear inner margin showing distinct evidence of coadaptation along the median line, and notched posteriorly in the vicinity of the single rounded eminence into which the ridge along the inner margin gradually rises. Adjacent to this eminence are to be seen in unworn specimens a few rows of small rounded tubercles, radiating outwards, but tending to become obliterated by use, and the larger eminence tending also to become worn down. Oral surface sloping gradually towards the bevelled external margin, but falling precipitately along the inner and posterior borders. Under surface displaying the characteristic ridges and depressions of Mylostomids, besides the usual groove for lodging remnants of the Meckelian cartilage. Jaw-angle acute, indicating a very slender, possibly anguilliform body.

Homologies of Mylostomid Dental Plates. — Throughout the foregoing section we have employed the term "palatal plates" merely as a convenient designation for the paired elements forming the upper pavement dentition of Mylostomids, without having precisely indicated their relations to other forms of crushing dentition. Newberry may possibly have assumed, although his writings nowhere indicate it, that these plates are homologous with the dental elements in the upper jaw of Dinichthys and other Arthrodires. He did, however, point out their obvious resemblance to the single pair of upper dental plates in Ceratodonts, his remarks on this subject being as follows:[1]

"The resemblance of the teeth which I have supposed formed the roof of the mouth to those of *Ceratodus* will strike any one who examines them, and no closer analogy suggests itself in the whole range of ichthyic dentition. There is, however, this marked difference, that while in *Ceratodus* there is only one pair of dentary [*i. e.*, dental] plates borne on the palato-pterygoid bones, in *Mylostoma* there were certainly several pairs of pavement teeth in the roof of the mouth. The spatulate bones which form the supports of the principal dental plates of the lower jaw evidently represent the thin, flattened, smooth, and once buried posterior end of the dentary bone [= splenial] in all of the Dinichthidae."

The earliest effort to trace homologies between the dentition of Mylostoma and Dinichthys is that of Bashford Dean, in 1901. Relying upon analogy with Dinichthys, he assumed that the upper dentition of Mylostoma must have been limited to two pairs of plates only; and finding that number to be present in the nearly complete example of *M. variabile* studied by him, he concluded that one of these pairs must correspond to the so-called "premaxillary" element, and the other to the so-called "maxillary" or "shear-tooth" of Dinichthys. Apparently the possibility did not occur to him that the two pairs of

[1] *Loc. cit.* (1889), p. 162.

tritoral plates in Mylostoma might together be equivalent to the single "maxillary" element, as it is commonly called in Dinichthys, and that a third pair of upper dental plates representing the "premaxillaries" were either actually or potentially present in Mylostoma. At all events greater weight was placed upon assumed numerical correspondence of dental plates in the two genera than upon morphological equivalence, for it is impossible to recognize the least similitude in form between the usual Arthrodiran "premaxillary" and either of the tabular crushing plates of Mylostoma. Denying that Arthrodires belong to Pisces proper, and that they have gill-arch jaws, he holds that their dental apparatus is non-homologous with that of all other fishes.

According to the present writer's interpretation, the two pairs of Mylostomid palatal plates are together equivalent to the single pair of "maxillary" elements in the Coccosteid type of dentition, this latter being regarded merely as a modification of the Mylostomid, adapted for cutting instead of crushing. That the upper dentition of Mylostoma consists in all of three pairs of plates, the foremost of which is the precise morphological equivalent of the so-called "premaxillary" pair in Dinichthys, is to be inferred not only from analogy with Dinomylostoma, in which this number has been definitely proved to obtain,[1] but from the remarkable constancy of form displayed by the more forwardly placed element in all Arthrodiran genera where it is known to occur. Unacquainted though we be with actual specimens, the existence of vomerine teeth in Mylostoma, real or potential, is an assured fact.

It follows from the point of view just stated that the Mylostomid and Dinichthyid types of dentition are reducible to a common plan, and this plan is further seen to be identical with that found in Dipnoans. The one element which by virtue of its function retains a constant form among Coccosteans generally, and in at least one genus of Mylostomids, is that commonly known as the "premaxillary," in reality the *vomerine* tooth; and the palatal plates (or more properly the palato-pterygoids) of the more primitive Mylostomid type are seen to have become fused, turned upright, and sharpened into a cutting edge along their functional margin in the more specialized Dinichthyid type.

[1] The recently published suggestion on the part of Dr. Hussakof (Mem. Amer. Mus. Nat. Hist. 1906, 9, p. 119) that the type of *Dinomylostoma beecheri* includes portions of more than one individual, all embedded in a single block of shale, is now abandoned by that writer as the result of further study of the original material. This statement is made here with Dr. Hussakof's consent.

The Mylostomid is properly regarded as the more primitive type of dentition on account of its obvious agreement with the Ceratodont, a fact previously noted by Newberry. And indeed, as he rightly observed, their resemblance is such as "will strike any one who examines them, and no closer analogy suggests itself in the whole range of ichthyic dentition." The combined evidence of dental, cranial, and most of the skeletal characters (the only marked exception being that of dermal armoring) furnishes wellnigh irresistible proof of the Dipnoan affinities of Arthrodires. A close parallel exists between the dentition of Mylostoma and Ceratodonts on the one hand, and Dinichthys and Protopterus on the other. The coincidence ceases to be remarkable when it is understood that other facts as well point to a common origin for Ceratodonts and Arthrodires. Very interesting also is Semon's observation that in the young of Neoceratodus the upper dental plates are at first divided into two pairs, as in Mylostomids, these afterwards combining into a single pair of palato-pterygoids.[1]

Adopting the view that the Arthrodiran type of dentition is strictly homologous with the Dipnoan, it is desirable to employ uniform designations for the dental parts. The tooth usually called "premaxillary" in the former group is therefore to be identified with the *vomerine* of typical Dipnoans, and the one or two succeeding pairs of "maxillaries" as the case may be, with the *palato-pterygoid* dental plates. The latter may be supposed to have been supported by the palato-pterygoid cartilage in Mylostoma precisely in the same manner as in Ceratodonts and Ctenodipterines. Their homologues in Dinichthys were no doubt situated well within the interior of the headshield, as we have a right to expect, at least, from analogy with Mylostoma. Some device is evidently required, owing to their large size, to take up the strains due to impact against the powerful lower dentition, and this we find actually provided for by the massive ridges developed on the under side of the headshield, whose position, direction, and inferred function suggest comparison with similar ridges in Neoceratodus.

Conclusions. — The consequences depending upon Dean's reconstruction of the Mylostomid dentition are as follows: The complete upper dentition of Mylostoma consists of two pairs of tritoral plates only, one of which is the functional, but not the morphological equivalent of the

[1] Consult in this connection the recently published conclusions of Prof. J. Graham Kerr on the genetic affinities of lower Gnathostomata, in his paper entitled Embryology of certain of the lower Fishes, and its bearing upon Vertebrate Morphology. Proc. Roy. Phys. Soc. Edinb. 1906, **16**, pp. 191-215.

"premaxillary" teeth in Dinichthys, and the other of the so-called "maxillary" or "shear-teeth." The hypothesis of an additional paired element in advance of these two, itself representing the "premaxillary" in Dinichthys, is not considered in the case of Mylostoma, and rejected in the case of Dinomylostoma. The tritoral plates are arranged in such manner that the mandibles cannot close against them directly so as to produce the observed marks of contact without operating by rotary movements, and without being capable of approximation and separation at their anterior extremities, — conditions which are unparalleled among Chordates. All the jaw-parts are regarded as of purely dermal origin, and therefore non-homologous with those of ordinary fishes. Their alleged structural differences, and assumed functional differences, make it necessary to exclude Arthrodires from fishes proper.

The consequences depending upon the newer reconstruction of the same materials are that all known Dinichthyids and at least one Mylostomid have a similar form of "premaxillary," which is the exact homologue of the vomerine teeth in Dipnoans, and that the succeeding pair or pairs (when two are present) of trenchant or crushing plates are homologous with the palato-pterygoid dental plates of typical Dipneusti. The jaws operate in the usual manner, are of the normal gill-arch type, and exhibit precisely the same conformation as those belonging to autostylic fishes. The combined evidence of the majority of characters of Arthrodires proves that they are specialized Dipnoans.

EXPLANATION OF PLATE.

Upper pavement dentition of *Mylostoma variabile* Newberry, from the Cleveland shale of Sheffield, Ohio. $\times \frac{1}{1}$. *a.p.p.*, anterior pair of palatopterygoid plates: *right* (Amer. Mus. Nat. Hist., Cat. 43 G), *left* (*idem*, 42 G). *p.p.p.*, posterior palatopterygoid plates: *right* (Amer. Mus. Nat. Hist. Cat. 3591), *left* (Mus. Comp. Zool. Cat. 1437). Specimens belonging to different individuals, rearranged in their inferred natural position.

Eastman.—Mylostomid Dentition.

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BY ALEXANDER AGASSIZ AND HUBERT LYMAN CLARK.

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No. 8. — *Preliminary Report on the Echini collected, in* 1902, *among the Hawaiian Islands, by the U. S. Fish Commission Steamer "Albatross," in charge of* COMMANDER CHAUNCEY THOMAS, U. S. N., *Commanding. By* ALEXANDER AGASSIZ *and* HUBERT LYMAN CLARK.

THE collection of Echini made by the U. S. F. C. S. "Albatross" in the spring of 1902 among the Hawaiian Islands is a very extensive one. A preliminary examination shows it to contain no less than 2,450 specimens distributed among 49 genera five of which are new, and 67 species of which 36 are new. It was hoped that the collection would extend to sufficient depths to show the connection of an oceanic insular fauna with the surrounding abyssal region. Unfortunately, as in the case of the Hawaiian starfishes,[1] the depths from which Echini were collected by the "Albatross" did not extend much beyond 500 fathoms. Of the 126 stations from which starfishes were obtained, only 11 were in depths greater than 500 fathoms; and of the 180 stations from which Echini were collected, only 14 were in greater depths than 500 fathoms; so that as regards these two groups of Echinoderms, the collections can only be considered as representing the fauna of the Hawaiian slopes to a depth of about 500 fathoms, and that at a comparatively short distance from the shore, the 1000-fathom line rarely being more than 20 miles, usually eight to ten miles, distant, and frequently, as around Hawaii,[2] much less. The species, therefore, naturally belong to what has been called the Continental fauna in an analysis of the known Echini prepared for the "Challenger" reports.[3] No dredgings containing Echini were made beyond 1278 fathoms, and none of the typical deep sea Echini already known from the Central Pacific, from the Panamic district, and from the tropical regions of the Eastern Pacific were collected.

The following species were recorded from the Hawaiian Islands previous to the visit of the "Albatross." Those which are not in the present

[1] The Starfishes of the Hawaiian Islands. By Walter K. Fisher. Bull. U. S. Fish Com. Vol. **23**, Part 3, p. 989. 1906.

[2] See Chart of the U. S. Hydrographic Office, No. 1368.

[3] The Voyage of H. M. S. "Challenger." Report on the Echinoidea, by Alexander Agassiz, p. 222, 232–237, 1881.

collection are marked with an *, and the name of the collection, in which there is a specimen from the Hawaiian Islands, follows in parentheses.

Cidaris metularia Bl.
Chondrocidaris gigantea A. Ag.
* Phyllacanthus verticillata A. Ag. (Mus. Godef.).
Diadema setosum (probably = *paucispinum* of this list).
* Echinothrix Desorii Pet. (M. C. Z.)
Echinothrix diadema Linné.
* Astropyga pulvinata Agass. ("Challenger").
Colobocentrotus atratus Br. (probably = *Quoyi* of this list).
Heterocentrotus mammillatus Br.
* Heterocentrotus trigonarius Br. (M. C. Z.).
Echinometra lucunter Bl. (= *Mathaei* of this list).
Echinometra oblonga Bl.
* Strongylocentrotus nudus A. Ag. (M. C. Z.).
* Pseudoboletia granulata A. Ag. (M. C. Z.).
Echinostrephus molare A. Ag.
* Mespilia globulosus Agass. (Mus. Godef.).
* Toxopneustes pileolus Agass. ("Challenger").
Hipponoë variegata A. Ag.
Fibularia australis Desml.
* Echinanthus testudinarius Gray (Breslau Mus.).
* Lovenia subcarinata Gray (Stockholm Mus.).
Brissus carinatus Gray.
Metalia maculosa A. Ag.
* Metalia sternalis Gray (M. C. Z.).
* Faorina chinensis Gray (M. C. Z.).

Of these 25 species it will be seen that 13 were collected by the "Albatross" in 1902. This is in noticeable contrast to the Hawaiian collection of starfishes, of which Dr. Fisher reports that only one of the ten species formerly known from the islands was dredged by the "Albatross." The absence of 12 of the previously recorded Echini is not surprising, as the collections hitherto have been made, with few exceptions, from along shore, while the collections made by the "Albatross" in 1902 were from off the shores to deep water. The bathymetrical range of several species is greatly extended, and a few Indo-Pacific species are added to the Hawaiian fauna, which now includes 79 species of Echini.

As regards the geographical relations of the Echini collected, it is interesting to note that of the new species of Cidaridae two are related to the Panamic fauna, the others to the Pacific or Indo-Pacific. The Salenias are Panamic, while the Aspidodiadematidae and many of the Diadematidae are Indo-Pacific. In the Echinothuridae we find *Phormosoma*

bursarium, an East Indian form, and Sperosoma, Indo-Pacific and Atlantic. The occurrence of a new species of Hemipedina is interesting, as well as that of Temnopleuridae of Indo-Pacific affinities, while none of the allied Australian genera have been collected. The number of interesting Clypeastroids collected is remarkable. Several of them are identical with or closely allied to, the Clypeastroids collected by the "Siboga" in the East Indian Archipelago, so that in this group the collection is typically Indo-Pacific. The peculiar Laganidae are East Indian and Japanese. A new genus of the closely circumscribed family of Echinoneidae, from shallow water, is an important addition to the Pacific Fauna.

A fair number of interesting Spatangoids were brought to light, though the dredgings did not extend to depths great enough to include the zone of the Urechinidae, Cystechinidae, and the like. Three genera of Palaeopneustidae were obtained, Phrissocystis, Meijerea, and a new genus (Pycnolampas) allied to Homolampas. The first two show affinities with the Panamic and East Indian echinid faunae and Pycnolampas with a Pacific and Atlantic type. Among the Spatangina are two species of Gymnopatagus, suggesting East Indian affinities, and two Loveniae, the one with East Indian the other with Panamic relations. A new Rhinobrissus and several species of Brissopsis are allied to East Indian and Pacific types. We may also mention the existence in the collection of two species of Aceste thus far known only from the dredgings of the "Challenger" in the Atlantic and Pacific, and the "Siboga" among the East Indian islands, at depths of 620 to 2600 fathoms. The Hawaiian species range only from 238 to 284 fathoms. Finally there is a fragment of a species of Periaster which must have been of gigantic size among the species of the genus.

DESMOSTICHA Haeckel

CIDARIDAE Müller.

Cidaris metularia Bl.
Dorocidaris calacantha A. Ag. and Clark.
Chondrocidaris gigantea A. Ag.
Phyllacanthus Thomasii A. Ag. and Clark.
Stephanocidaris hawaiiensis A. Ag. and Clark.
Stereocidaris grandis Död.
Stereocidaris leucacantha A. Ag. and Clark.
Porocidaris variabilis A. Ag. and Clark.
Acanthocidaris hastigera A. Ag. and Clark.

Descriptions of the above species, with numerous plates, have appeared in "Hawaiian and Other Pacific Echini. The Cidaridae," Mem. M. C. Z., **34**, No. 1, February, 1907. 42 pages, 44 plates.

SALENIDAE Agass.

Salenia miliaris A. Ag.

Salenia miliaris A. Agassiz, 1898. Bull. M. C. Z., **32**, No. 5, p. **74**; Plate 2, Figs. 2–4.

Small specimens of this Panamic species were collected at the following stations.

Station 4060. Off Alia Point Light, N. E. coast of Hawaii, 759–913 fathoms.
" 4125. Off Kahuku Point, Oahu, 963–1124 fathoms.
" 4181. Off Hanamaulu, Kauai, 671–811 fathoms.

Four specimens.

Salenia crassispina A. Ag. and Clark.

This species, although closely related to the preceding, is easily distinguished by the primary radioles which are remarkably stout, and although distinctly verticillate, are quite smooth. In *miliaris*, the greatest thickness of a radiole is much less than the diameter of its milled ring, while in *crassispina* the diameter of the spine is fully equal to, and may exceed that of its milled ring. The species is further remarkable for the comparatively slight depth at which it was taken.

Station 4045. Off Kawaihae Light, W. coast of Hawaii, 147–198 fathoms.

One specimen.

ARBACIADAE Gray.

Habrocidaris A. Ag. and Clark.

This genus is established for *Podocidaris scutata* A. Ag. of the West Indies, and for the following closely related species from the Hawaiian Islands. Although quite similar to Podocidaris A. Ag., and even more so to Pygmaeocidaris Död., it may be readily distinguished from both by the very thin and delicate test, the regular and very slightly indented actinal system, the close plating of the entire buccal membrane, and the distinctly triangular primary radioles.

Habrocidaris argentea A. Ag. and Clark.

This species is closely allied to *H. scutata* A. Ag. from Santa Cruz (580 fms.). It is at once distinguished by the much larger abactinal system, the different shape of the ocular plates, and the distinctly pentagonal actinal system. The single specimen taken is 11.5 mm. in diameter, with the abactinal system 7 mm., the anal system 2 mm., and the actinal system 6 mm. Unfortunately all the primary radioles are broken and only the basal portions of a few remain attached to the test. These radioles are triangular in cross-section and the three edges, though rounded, project conspicuously from the solid axis. The test is silvery, tinged with brown, while the primary radioles were evidently white.

Station 3973. Near French Frigate Shoal; 23° 47′ 10″ N. — 166° 24′ 55″ W.; 395–397 fathoms.

ASPIDODIADEMATIDAE Duncan.

Aspidodiadema nicobaricum Död.

Aspidodiadema nicobaricum Döderlein, 1901. Zool. Anz. Bd. **24**, p. 21.

This species was taken at many stations, and in considerable numbers. The specimens are much smaller than those described by Döderlein, as the largest is only 25 mm. in diameter, while his were 33–39 mm. There are also slight differences in color, the Hawaiian specimens being much paler.

Station 3892. Off Mokapu Islet, N. coast of Molokai, 328–414 fathoms.
" 3981. Off Nawiliwili Light, Kauai, 414–636 fathoms.
" 3988. Off Hanamaulu, Kauai, 165–469 fathoms.
" 3989. Off Hanamaulu, Kauai, 385–500 fathoms.
" 3994. Off Mokuaeae Islet, Kauai, 330–382 fathoms.
" 4013. Off Hanamaulu, Kauai, 399–419 fathoms.
" 4014. Off Hanamaulu, Kauai, 362–399 fathoms.
" 4021. Off Hanamaulu, Kauai, 286–399 fathoms.
" 4022. Off Hanamaulu, Kauai, 374–399 fathoms.
" 4025. Off Mokuaeae Point, Kauai, 275–368 fathoms.
" 4030. Off Ukula Point, Kauai, 423–438 fathoms.
" 4107. Off Lae-o Ka Laau Light, Molokai, 350–355 fathoms.
" 4110. Off Lae-o Ka Laau Light, Molokai, 449–460 fathoms.
" 4112. Off Lae-o Ka Laau Light, Molokai, 433–447 fathoms.
" 4131. Off Hanamaulu, Kauai, 257–309 fathoms.
" 4137. Off Hanamaulu, Kauai, 411–476 fathoms.
" 4140. Off Hanamaulu, Kauai, 339–437 fathoms.
" 4141. Off Hanamaulu, Kauai, 437–632 fathoms.
" 4166. Off Modu Manu, 293–800 fathoms.
" 4177. Off Kawahioa Point, Niihau, 319–451 fathoms.
" 4180. Off Kawahioa Point, Niihau, 417–426 fathoms.
" 4187. Off Hanamaulu, Kauai, 508–703 fathoms.

The average depth at these stations is 424 fathoms and there is no reason to believe that any specimens of this species were taken in less than 300 fathoms.

One hundred and sixty-nine specimens.

Aspidodiadema meijerei A. Ag. and Clark.

Aspidodiadema nicobaricum var. *meijerei* Döderlein, 1906. Echin. Deutsch. Tiefsee-Exp., p. 165.

A large series of this form was taken by the "Albatross," and as it seems to show constant characters, we look upon it as a distinct species, although the features on which it is based are slight. Besides the striking difference in color of the primary spines, there is a slight difference in the relative size of the abactinal and anal systems. In the Hawaiian specimens of *nicobaricum*, the primary spines are very pale purplish, the actinal surface of the test tends to become deep purple,

the diameter of the abactinal system is rather more than half the diameter of the test, and the anal system is nearly three-fourths of the abactinal; while in the specimens of *meijerei*, the primary spines are bright green, the *abactinal* surface tends to become deep purple, the diameter of the abactinal system about equals one-half that of the test, and the anal system is about two-thirds of the abactinal. The specimens of *meijerei* are on the whole much larger than those of *nicobaricum*, some of them being over 30 mm. in diameter. They also come from more shallow water, and only from the vicinity of Molokai and southern Oahu, as the following list of stations shows.

Station 3817. Off Diamond Head, Oahu, 320 fathoms.
" 3818. Off Diamond Head, Oahu, 293–295 fathoms.
" 3836. Off Lae-o Ka Laau Light, Molokai, 238–255 fathoms.
" 3839. Off Lae-o Ka Laau Light, Molokai, 259–266 fathoms.
" 3865. Off Mokuhooniki Islet, Pailolo Channel, 256 fathoms.
" 3914. Off Diamond Head, Oahu, 289–292 fathoms.
" 3918. Off Diamond Head, Oahu, 257–294 fathoms.
" 3920. Off Diamond Head, Oahu, 265–280 fathoms.
" 4096. Off Mokuhooniki Islet, Pailolo Channel, 272–286 fathoms.
" 4097. Off Mokuhooniki Islet, Pailolo Channel, 286 fathoms.
" 4105. Off Lae-o Ka Laau Light, Molokai, 314–335 fathoms.
" 4116. Off Kahuku Point, Oahu, 241–282 fathoms.
" 4122. Off Barber's Point Light, Oahu, 192–352 fathoms.
" 4178 (?). Off Kawahioa Point, Niihau, 319–378 fathoms.

The average depth of these stations is 280 fathoms, and there is no reason to believe that any specimens of this species were taken in more than 320 fathoms.

One hundred and forty-four specimens.

DIADEMATIDAE Peters.

Diadema paucispinum A. Ag.

Diadema paucispinum A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 19.

These specimens are certainly distinct from West Indian specimens and equally so from *mexicanum* and *savignyi*; it therefore seems advisable to recognize *paucispinum* once more.

Puako Bay, Hawaii.
Honolulu.
Station 3968. French Frigate Shoal, $14\frac{1}{2}$–$16\frac{1}{2}$ fathoms
" 4169. Off Modu Manu, 21–22 fathoms.
Nine specimens.

Echinothrix calamaris A. Ag.

Echinus calamaris Pallas, 1774. Spic. Zool. **1**, fasc. 10, p. 31; Plate 2, Figs. 4–8.
Echinothrix calamaris A. Agassiz, 1872. Rev. Ech. Pt. 1, p. 119.

Only young specimens were collected, the largest being 30 mm. in diameter.
Puako Bay, Hawaii.

Station 4033. Penguin Bank, S. coast of Oahu, 28–29 fathoms.
Two specimens.

Echinothrix turcarum Pet.

Diadema turcarum Schynvien, 1711. Thes. Imag., p. 2; Plate 14, Fig. B.
Echinothrix turcarum Peters, 1853. Monatsb. Akad. Berlin, p. 484.

A good series of adults and young, ranging from 25 to 80 mm. in diameter, was taken at Puako Bay, Hawaii, and at Honolulu.

Twelve specimens.

Astropyga radiata Gray.

Cidaris radiata Leske, 1778. Klein Nat. dis. Ech., p. 116; Plate 44, Fig. 1.
Astropyga radiata Gray, 1825. Ann. Phil. **10**, p. 2.
Only a single very small specimen (diameter, 26 mm.) is in the collection.
Station 3875. Auau Channel, between Maui and Lanai, 34–65 fathoms.

Centrostephanus asteriscus A. Ag. and Clark.

This very pretty little species is easily distinguished from other members of the genus by the large number of coronal plates and the peculiar abactinal system. In a specimen only 3.5 mm. in diameter there are already eight coronal plates, while an individual 14 mm. in diameter has 13. The ocular plates are small and nearly or quite excluded from the medium-sized anal system, which is closely covered with very small plates. The oculars are more completely excluded in the larger specimen than in the smaller ones. The genital pores are conspicuous. The buccal plates carry spines as well as pedicellariae. The color is light reddish. becoming reddish-white actinally, and the primary radioles are prettily banded with red and whitish; from the end of each ambulacrum a conspicuous white line runs straight to the centre of the anal system, the five lines forming a conspicuous star on the red abactinal surface; the lines are broadest in the smallest specimen and become narrower (relatively) with age. The largest specimen taken has the test 14 mm. in diameter and 6.25 mm. high, the abactinal system 5.5 mm., and the actinal system 6 mm. The primary radioles, the longest of which measure 20 mm., are provided with rather widely spaced whorls of very minute, sharp spinelets.

Station 4034. Penguin Bank, S. coast of Oahu, 14–28 fathoms.
" 4066. Off Ka Lae-o Ka Ilio Point, Maui, 49–176 fathoms.
" 4128. Off Hanamaulu, Kauai, 68–253 fathoms.
" 4161. Off Modu Manu, 39–183 fathoms.
" 4163. Off Modu Manu, 24–40 fathoms.
Five specimens.

Chaetodiadema pallidum A. Ag. and Clark.

Of this interesting genus, a handsome new species proves to be common in certain localities among the Hawaiian Islands. It is sharply distinguished from the

two species hitherto known by the coloration, which is pale buff above when dry, more or less tinged with purple when wet, becoming buffy-white beneath. The sides of the bare interambulacral areas on the abactinal surface are more or less distinctly yellow; in many specimens the ambulacral edge of this area is marked by a broad, dull red line extending from the ambitus to the genital plate, but these lines may be interrupted and in about half the specimens are entirely wanting. On the actinal side, some individuals have a deep brown line forming a more or less perfect pentagon around the actinostome, about one-third of the distance to the ambitus. The primary radioles are slender, of moderate but variable length, the longest equalling the diameter of the test, and are decidedly flattened. They are nearly white, but many have a purplish longitudinal stripe on the abactinal side, and not infrequently they are handsomely banded with purple. There is no blue anywhere on test or spines. The tuberculation of the test is more like that of *granulosum* than of *japonicum*, but there are only eight series of primary interambulacral tubercles at the ambitus even in the largest individuals. The specimens range in diameter from 42 to 70 mm. The test is very flat, the height being only .25–.30 of the diameter. The abactinal system is .30–.42 and the actinal only .17–.24 of the diameter, while the anal system is .60–.65 of the abactinal. The test is relatively higher and the abactinal and actinal systems larger in small than in large individuals.

Station 3856. Pailolo Channel, between Maui and Molokai, 127 fathoms.
" 3857. Pailolo Channel, between Maui and Molokai, 127–128 fathoms.
" 3957. Vicinity of Laysan Island, 173–220 fathoms.
" 4103. Pailolo Channel, between Maui and Molokai, 132–141 fathoms.
" 4104. Pailolo Channel, between Maui and Molokai, 123–141 fathoms.

Eighty-two specimens.

Leptodiadema A. Ag. and Clark.

This genus is established for a very small Diadematoid, which is apparently quite different from any known genus. The size, form, and spines remind one of Lissodiadema and the abactinal system is not altogether unlike that genus, but the tuberculation is entirely different. Test flattened, both abactinally and actinally. Ambulacra narrow, with pores in single straight series, not becoming crowded at actinostome. Each ambulacrum carries a double series of primary tubercles, extending from abactinal system to actinostome. Coronal plates numerous (13–14 in specimen 9 mm. in diameter), each with a large primary tubercle, at outer end. Below the ambitus, these tubercles are increasingly nearer centre of plate, so that the two series of them converge and meet in a point at actinostome. Beginning with the fifth (from abactinal system), each coronal plate carries a second somewhat smaller tubercle, at inner end, and these two series terminate about four plates from actinostome. Secondary spines few; miliaries almost wanting. Primary tubercles, low, perforate, apparently finely crenulate, those of the ambulacra smaller than those of the interambulacra. Abactinal system moderate, with oculars on each side of madreporic plate excluded

from anal system; other oculars narrowly in contact with the single series of large anal plates. Genital openings of only moderate size. Anal papilla conspicuous. Actinostome somewhat larger than abactinal system; actinal cuts slight. Buccal membrane closely covered with plates as in young Diadema. Primaries delicate, glassy, slightly curved, blunt, with 5–7 prominent ridges, bearing few scattered, very slender teeth, about equal to half the diameter of the test; those of the ambulacra scarcely shorter or more slender than the others.

Leptodiadema purpureum A. Ag. and Clark.

The single specimen is only 9 mm. in diameter. The color is dull purplish, becoming bright purple on the buccal membrane. The spines are nearly colorless.

Station 3847. Off Lae-o Ka Laau Light, Molokai, 23–24 fathoms.

ECHINOTHURIDAE Wyv. Thoms.

Phormosoma bursarium A. Ag.

Phormosoma bursarium A. Agassiz, 1881. Rep. Chall. Ech. p. 99; Plate 10 b.

An excellent series of this species, ranging from 23 to 110 mm. in diameter, was taken at the following stations.

Station 3884. Pailolo Channel, between Maui and Molokai, 284–290 fathoms.
" 3892. Off Mokapu Islet, N. coast of Molokai, 328–414 fathoms.
" 3904. Off Mokapu Islet, N. coast of Molokai, 295 fathoms.
" 3957. Off Laysan Island, 173–220 fathoms.
" 3988. Off Hanamaulu, Kauai, 165–469 fathoms.
" 3994. Off Mokuaeae Islet, Kauai, 330–382 fathoms.
" 3997. Off Ukula Point, Kauai, 418–429 fathoms.
" 4019. Off Hanamaulu, Kauai, 409–550 fathoms.
" 4022. Off Hanamaulu, Kauai, 374–399 fathoms.
" 4025. Off Mokuaeae Point, Kauai, 275–368 fathoms.
" 4087. Off Mokuhooniki Islet, Pailolo Channel, 306–308 fathoms.
" 4089. Off Mokuhooniki Islet, Pailolo Channel, 297–304 fathoms.
" 4091. Off Mokuhooniki Islet, Pailolo Channel, 306–308 fathoms.
" 4110. Off Lae-o Ka Laau Light, Molokai, 449–460 fathoms.
" 4111. Off Lae-o Ka Laau Light, Molokai, 460–470 fathoms.
" 4112. Off Lae-o Ka Laau Light, Molokai, 433–447 fathoms.
" 4113. Off Lae-o Ka Laau Light, Molokai, 395–433 fathoms.
" 4141. Off Hanamaulu, Kauai, 437–632 fathoms.

One hundred and fifty-four specimens.

Sperosoma obscurum A. Ag. and Clark.

The large series of Sperosomas collected cannot be referred to any of the previously known species. The coloration is somewhat variable, for while most of the specimens are more or less decidedly violet or purple, some large ones are distinctly gray or yellowish-brown. The plates are not outlined in white (as in the

other species) but are frequently quite plainly outlined in some shade *darker* than the test, though they are often very indistinct. The ambulacral and interambulacral areas are nearly equal in width at the ambitus but the interambulacra may be somewhat broader. The pores on the abactinal surface are arranged in a double series on each side of the ambulacrum but the *outer* series contains fifty per cent more pores than the inner, and a quincunx arrangement is seldom visible. There are very few large tubercles on the abactinal surface (about 35 in the largest specimen), and relatively few actinally; the latter are confined to the plates near the ambitus. The greater part of the actinal surface, especially about the actinostome, is closely covered with small tubercles of more or less uniform size, giving an appearance not wholly unlike *Chaetodiadema*; this is most marked in large individuals. The specimens taken range from 20 to 220 mm. in diameter.

Station 3824. Off Lae-o Ka Laau Light, Molokai, 222–498 fathoms.
" 3865. Pailolo Channel, between Maui and Molokai, 256–283 fathoms.
" 3979. Off Modu Manu, 222–387 fathoms.
" 3988. Off Hanamaulu, Kauai, 165–469 fathoms.
" 4015. Off Hanamaulu, Kauai, 318–362 fathoms.
" 4021. Off Hanamaulu, Kauai, 286–399 fathoms.
" 4025. Off Mokuaeae Point, Kauai, 275–368 fathoms.
" 4036. Off Kawaihae Light, W. coast of Hawaii, 687–692 fathoms.
" 4089. Off Mokuhooniki Islet, Pailolo Channel, 297–306 fathoms.
" 4096. Off Mokuhooniki Islet, Pailolo Channel, 272–286 fathoms.
" 4112. Off Lae-o Ka Laau Light, Molokai, 433–447 fathoms.
" 4117. Off Kahuku Point, Oahu, 253–282 fathoms.
" 4130. Off Hanamaulu, Kauai, 283–309 fathoms.
" 4131. Off Hanamaulu, Kauai, 257–309 fathoms.
" 4134. Off Hanamaulu, Kauai, 225–324 fathoms.
" 4136. Off Hanamaulu, Kauai, 294–352 fathoms.
" 4137. Off Hanamaulu, Kauai, 411–476 fathoms.

Thirty-nine specimens.

ECHINOMETRIDAE Gray.

Heterocentrotus mammillatus Br.

Cidaris mammillata Klein, 1734. Nat. disp. Ech. p. 19; Plate 6, Figs. A, B.
Heterocentrotus mammillatus Brandt, 1835. Prod. Desc. Anim., p. 266.

All the specimens of Heterocentrotus in the collection are referable to this species.

Laysan Island, and Puako Bay, Hawaii.

Twenty-four specimens.

Colobocentrotus Quoyi Br.

Echinus Quoy de Blainville, 1825. Dict. Sci. Nat. **37**, p. 96.
Colobocentrotus Quoyi Brandt, 1835. Prod. Desc. Anim., p. 267.

A large series of Colobocentrotus was taken but all are referable to this single species, and show little variation.

Necker Island.
Lanai Island.
Puako Bay, Hawaii.
Kamalino Bay, Niihau.
Napeli, Maui.
One hundred and three specimens.

Echinometra Mathaei Bl.

Echinus Mathaei de Blainville, 1825. Dict. Sci. Nat., **37**, p. 94.
Echinometra Mathaei de Blainville, 1834. Man. d'Actin., p. 225.

The series of Echinometras is quite easily divisible into two sets, one of which consists of individuals with high, usually elongated tests, large tubercles, stout spines and relatively small (.17–.23 of long diameter) abactinal system. These are evidently the wide-ranging and common *Mathaei* (formerly called *lucunter*).

Honolulu reefs.
Kamalino Bay, Niihau.
Laysan Island.
Station 3959. Off Laysan Island, 10 fathoms.
Thirteen specimens.

Echinometra picta A. Ag. and Clark.

The other set of Echinometras has the test much flatter, the height rarely over .50 of the long diameter, the abactinal system larger (.24–.30 of the long diameter), the tubercles smaller, giving the abactinal surface a much more bare appearance than in *Mathaei*, and the spines longer and more slender. These two forms are not sharply set off from each other, but there are few individuals which cannot be distinguished at a glance, and it seems desirable to give the flat individuals a name. Similar specimens are in the Museum collection from the Society Islands, but not from the East Indies, or west thereof. This species seems to bear the same relation to *Mathaei* that *viridis* of the West Indies does to *lucunter* (formerly called *subangularis*).

Honolulu reefs.
Puako Bay, Hawaii.
Necker Island.
Kamalino Bay, Niihau.
Napeli, Maui.
Station 3975. Off Necker Island Shoal, 16–171 fathoms.
Twenty-nine specimens.

Echinometra oblonga Bl.

Echinus oblongus de Blainville, 1825. Dict. Sci. Nat., **37**, p. 95.
Echinometra oblonga de Blainville, 1834. Man. d'Actin., p. 225.

A good series of this species was taken, none of which show the least approach to *mathaei* or afford the slightest difficulty in identification, without reference to the spicules in the pedicels ! (vide de Meijere, 1904, and Döderlein, 1906).

Puako Bay, Hawaii.
Honolulu reefs.
Lanai Island.
Necker Island.
Hanalei, Kaui.
Kamalino Bay, Niihau.
Laysan Island.
Thirty-eight specimens.

Echinostrephus molare A. Ag.

Echinus molaris de Blainville, 1825. Dict. Sci. Nat. 37, p. 88.
Echinostrephus molare A. Agassiz, 1872. Rev. Ech. Plate 1, p. 119.

A good series of this species is in the collection.
Laysan Island.
Station 3959. Off Laysan Island, 10 fathoms.
" 3960. Off Laysan Island, 10–19 fathoms.
" 3968. French Frigate shoal, $14\frac{1}{2}$–$16\frac{1}{2}$ fathoms.
" 3969. French Frigate Shoal, 15–16 fathoms.
" 3970. French Frigate Shoal, 17–$17\frac{1}{2}$ fathoms.
" 3975. Off Necker Island Shoal, 16–171 fathoms.
" 4147. Off Modu Manu, 26 fathoms.
Twenty specimens.

TEMNOPLEURIDAE Desor.

Trigonocidaris albidoides A. Ag. and Clark

This is the Pacific representative of *T. albida* of the West Indies, and is closely allied to that species. It differs in having the test less clearly and deeply sculptured, especially abactinally, and in having more spines on the abactinal system. But the most obvious differences are in coloration: adult West Indian specimens have the abactinal system, especially the genital plates, and many of the primary tubercles very decidedly reddish, while the primary spines are pure white; the Hawaiian specimens have no trace of red on the test or tubercles, but some or all of the primaries, especially actinally, are distinctly banded or tipped with red. Of course young specimens (under 4 mm.) do not show these differences, but in adults they are quite evident. The specimen in the "Siboga" collection which had orange-banded spines, referred by de Meijere with some hesitation to *albida*, is evidently the Pacific form.

Station 3859. Off Mokuhooniki Islet, Pailolo Channel, 138–140 fathoms
" 3863. Off Mokuhooniki Islet, Pailolo Channel, 127–154 fathoms.
" 3892. Off Mokapu Islet, N. coast of Molokai, 328–414 fathoms.
" 4045. Off Kawaihae Light, W. coast of Hawaii, 147–198 fathoms.

Five specimens.

Orechinus monolini Död.

Trigonocidaris monolini A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 203.
Orechinus monolini Döderlein, 1905. Zool. Anz., **28**, p. 622.

An excellent series of this rare and interesting species was taken by the "Albatross." It is notable for the large size of many of the specimens, which range from 6 to 22 mm. in diameter.

Station 3839. Off Lae-o Ka Laau Light, Molokai, 259–266 fathoms.
" 3865. Off Mokuhooniki Islet, Pailolo Channel, 256–283 fathoms.
" 3914. Off Diamond Head, Oahu, 289–292 fathoms.
" 3918. Off Diamond Head, Oahu, 257–294 fathoms.
" 4085. Off Puniawa Point, Maui, 267–283 fathoms.
" 4117. Off Kahuku Point, Oahu, 253–282 fathoms.
" 4125. Off Kahuku Point, Oahu, 963–1124 fathoms.
" 4126. Off Kahuku Point, Oahu, 743–1278 fathoms.
" 4131. Off Hanamaulu, Kauai, 257–309 fathoms.

Twenty-nine specimens.

Prionechinus chuni Död.

Prionechinus chuni Döderlein, 1906. Ech. Deuts. Tiefsee Exp., p. 192; Plate 24, Fig. 3.

A small, but very good, series of this interesting little urchin, ranging from 2.5 to 11 mm. in diameter, was taken at the following station. Döderlein's admirable description, coupled with the photographs he gives, leaves no doubt as to the identity of these specimens.

Station 4126. Off Kahuku Point, Oahu, 743–1278 fathoms.

Seven specimens.

Prionechinus sculptus A. Ag. and Clark.

This species is distinguished from the four previously known species of the genus, as limited by Döderlein (1906), by the very small and distinct buccal plates, with five pairs of buccal feet, the smooth, longitudinally striated primary spines, and the handsomely sculptured and ornamented abactinal system. The genital opening is near the centre of the plate. The test is not so high as in the preceding species and the anal plates, are much less numerous, with one evidently larger than the rest. The color is dull purplish-red, very pale in the smaller specimens. The primaries are white, but the longitudinal striations are purplish. The specimens range from 2 to 10 mm. in diameter.

Station 3818. Off Diamond Head, Oahu, 293–295 fathoms.
" 4028. Off Ukula Point, Kauai, 444–478 fathoms.
" 4039. Off Kawaihae Light, Hawaii, 670–697 fathoms.
" 4083. Off Puniawa Point, Maui, 238–253 fathoms.
" 4086. Off Puniawa Point, Maui, 283–308 fathoms.
" 4087. Off Mokuhooniki Islet, Pailolo Channel, 306–308 fathoms.
" 4088. Off Mokuhooniki Islet, Pailolo Channel, 297–306 fathoms.
" 4115. Off Kahuku Point, Oahu, 195–241 fathoms.

Sixty-seven specimens.

Prionechinus depressus A. Ag. and Clark.

The specimens to which we have given this name were taken with the preceding, but the larger individuals (those over 4 mm. in diameter) are so obviously different that the two are easily separated. In this species, the test is very flat and the bare, interambulacral grooves are very conspicuous. The abactinal system is entirely different from that of *P. sculptus,* as there is very little sculpturing, and the genital openings are situated at the extreme distal tip of the plates, in a groove which is continuous with the interambulacral groove. The spines, color and size are as in *sculptus.* While it is not impossible that this species and the preceding are simply the two sexes of one species, such sexual dimorphism is not at present known among the regular Echini.

Station 3818. Off Diamond Head, Oahu, 293–295 fathoms.
" 4028. Off Ukula Point, Kauai, 444–478 fathoms.
" 4083. Off Puniawa Point, Maui, 238–253 fathoms.
" 4086. Off Puniawa Point, Maui, 283–308 fathoms.
" 4088. Off Mokuhooniki Islet, Pailolo Channel, 306–308 fathoms.

Forty-five specimens.

Pleurechinus hawaiiensis A. Ag. and Clark.

Although this species is closely allied to *P. siamensis* Mortensen, it differs decidedly in color and in one or two details of structure. The abactinal interambulacral space is not at all bare, but on the other hand there are only half as many secondary and miliary tubercles on the ambulacral and interambulacral plates near the ambitus, as in the specimen of *siamensis* figured in detail by Mortensen (1904). The anal system is covered by several large plates and a few small ones, and the anus is subcentral. The color of the test is prevailingly green, with the abactinal interambulacra lighter and often pure white in striking contrast. The primaries are whitish with more or less red. The tendency towards a bright red coloration is noticeable and two specimens are almost uniformly bright red, test as well as spines. Around the actinostome the test often becomes whitish, while abactinally it is frequently marked with purplish-brown. While the color is thus very variable, there is no tendency to approach the coloration of *siamensis,* except as each species has a bright red variety.

Station 3823. Off Lae-o Ka Laau Light, Molokai, 78–222 fathoms.
" 3847. Off Lae-o Ka Laau Light, Molokai, 23–24 fathoms.
" 3871. Off Mokuhooniki Islet, Auau Channel, 13–43 fathoms.
" 3872. Off Mokuhooniki Islet, Auau Channel, 32–43 fathoms.
" 3876. Off Lahaina Light, Maui, 28–43 fathoms.
" 3962. Off Laysan Island, 16 fathoms.
" 3978. Off Modu Manu, 32–46 fathoms.
" 4148. Off Modu Manu, 26–33 fathoms.
" 4150. Off Modu Manu, 71–160 fathoms.

Sixteen specimens.

TRIPLECHINIDAE A. Ag.

Hemipedina indica de Meij.

Hemipedina indica de Meijere, 1903. Tijds. Ned. Dierk. Vereen. (2) **8**, p. 3.

The small series of this Oriental species, taken by the "Albatross," is of particular interest from the large size of most of the specimens, which range from 15 to 37 mm. They agree well with de Meijere's description, even in coloration, which shows little variation except in depth. The larger specimens have the test more flattened than the young ones, and its color is distinctly purple, while the actinostome is relatively smaller. It seems to us very unlikely that *mirabile* is a synonym of *indica,* as Döderlein now supposes.

Station 3865. Pailolo Channel, between Maui and Molokai, 256–283 fathoms.
" 3879. Off Molokini Islet, south of Lanai, 923–1081 fathoms.
" 3914. Off Diamond Head, Oahu, 289–292 fathoms.
" 4178. Off Kawahioa Point, Niihau, 319–378 fathoms.
" 4179. Off Kawahioa Point, Niihau, 378–426 fathoms.

Eleven specimens.

Hemipedina pulchella A. Ag. and Clark.

This beautiful little Echinoid may be recognized at once by the remarkable interambulacral primary radioles and the showy coloration. The test is white, becoming rosy abactinally (the ocular and genital plates of the larger specimen are quite red); the anal system is contrastingly white. The ambulacral primaries and the very few secondary spines are pure white, while the interambulacral primaries are bright yellowish-green at the base, pink in the middle, and whitish or pure white at the tip; the colors are not sharply separated, but shade into each other. The primaries of the abactinal coronal plates are one and a half times as long as the diameter of the test, or less; they are very stout (the thickness 8-10 per cent of the length) and closely resemble those of Echinometra. In the larger specimen the test is 14 mm. in diameter, and the abactinal and actinal systems each about one half as much. The anal system is remarkably small, decidedly smaller than a single genital plate, and is covered by a few (20) rounded plates. The genital opening is near the centre of the plate.

Station 3991. Off Mokuaeae Islet, Kauai, 272–296 fathoms.

Two specimens.

Psammechinus verruculatus Ltk.

Psammechinus verruculatus Lütken, 1864. Vid. Med., p. 166.

All the specimens are small, the largest being only 12 mm. in diameter, but they correspond well to de Loriol's (1883) figures and description, with the exception that the poriferous zones, on the bare test, are red or reddish, instead of greenish.

Station 3847. Off Lae-o Ka Laau Light, Molokai, 23–24 fathoms.
" 3871. Off Mokuhooniki Islet, Auau Channel, 13–43 fathoms.
" 3872. Off Mokuhooniki Islet, Auau Channel, 32–43 fathoms.
" 3955. Off Laysan Island, 20–30 fathoms.
" 3970. French Frigate Shoal, 17–17½ fathoms.
" 4031. Off Diamond Head, Oahu, 27–28 fathoms.
" 4032. Off Diamond Head, Oahu, 27–29 fathoms.
" 4149. Off Modu Manu, 33–71 fathoms.
" 4162. Off Modu Manu, 21–24 fathoms.
" 4168. Off Modu Manu, 20–21 fathoms.
Sixteen specimens.

Psammechinus paucispinus A. Ag. and Clark.

This species differs very decidedly from the preceding, and from other allied forms, in the small number of secondary and miliary spines and tubercles, and yet the abactinal interambulacra are not bare, as in *Toxopneustes semituberculatus*. The vertical sutures, especially in the interambulacra, are abactinally very distinct and somewhat depressed. There is one large primary tubercle on each ambulacral and interambulacral plate. Each ambulacral plate near the ambitus bears one secondary and two miliary tubercles and each interambulacral plate has a large secondary (or small primary) tubercle at each end and carries five or six small miliaries. The pore-pairs are in arcs of four. The abactinal system is about .33 of the diameter of the test, and only one ocular plate reaches the somewhat excentric anal system. The actinal system is more than .50 of the diameter. The test is whitish with a more or less pronounced green tinge when cleaned, while the spines vary from white to deep pink; four of the five specimens appear decidedly pink.

Station 3872. Off Mokuhooniki Islet, Auau Channel, 32–43 fathoms.
" 3876. Off Lahaina Light, Maui, 28–43 fathoms.
" 4033. Off Diamond Head, Oahu, 28–29 fathoms.
" 4164. Off Modu Manu, 40–56 fathoms.
Five specimens.

Hipponoë variegata A. Ag.

Cidaris variegata Leske, 1778. Kleins Nat. disp. Ech., p. 85.
Hipponoë variegata A. Agassiz, 1872. Rev. Ech. Plate 1, p. 135.

A good series of this variable species was obtained; the largest is 145 mm. in diameter and wholly white.

Honolulu.
Puako Bay, Hawaii.
Station 3876. Off Lahaina Light, Maui, 28–43 fathoms.
Twenty-seven specimens.

CLYPEASTRIDAE Agass.

FIBULARINA Gray.

Echinocyamus scaber de Meij.

Echinocyamus scaber de Meijere, 1903. Tijds. Ned. Dierk. Ver. (2) **8**, p. 5.

With one exception the specimens are bare tests, but all agree well with de Meijere's description and figures.

Station 3839. Off Lae-o Ka Laau Light, Molokai, 259–266 fathoms.
" 3908. Off Diamond Head, Oahu, 304–308 fathoms.
" 3914. Off Diamond Head, Oahu, 289–292 fathoms.

Five specimens.

Fibularia australis Desml.

Fibularia australis Desmoulins, 1837. Tabl. Syn., p. 240.

With two exceptions the specimens are bare tests, and all are very small.

Station 3846. Off Lae-o Ka Laau Light, Molokai, 60–64 fathoms.
" 4045. Off Kawaihae Light, Hawaii, 147–198 fathoms.
" 4064. Off Kauhola Light, Hawaii, 63–107 fathoms.
" 4148. Off Modu Manu,, 26–33 fathoms.

Seven specimens.

ECHINANTHIDAE A. Ag.

Clypeaster scutiformis Lamk.

Echinus scutiformis Gmelin, 1788. Linn. Sys. Nat., p. 3184.
Clypeaster scutiformis Lamarck, 1816. Anim. s. Vert. **3**, p. 14.

An excellent series, ranging from 10 to 48 mm. in length, is in the collection from the following stations, and only twenty-three are bare tests.

Station 3846. Off Lae-o Ka Laau Light, Molokai, 60–64 fathoms.
" 3847. Off Lae-o Ka Laau Light, Molokai, 23–24 fathoms.
" 3848. Off Lae-o Ka Laau Light, Molokai, 44–73 fathoms.
" 3849. Off Lae-o Ka Laau Light, Molokai, 43–73 fathoms.
" 3850. Off Lae-o Ka Laau Light, Molokai, 43–66 fathoms.
" 3863. Off Mokuhooniki Islet, Pailolo Channel, 127–154 fathoms.
" 3871. Off Mokuhooniki Islet, Pailolo Channel, 13–43 fathoms.
" 3872. Off Mokuhooniki Islet, Pailolo Channel, 32–43 fathoms.
" 3874. Off Mokuhooniki Islet, Pailolo Channel, 21–28 fathoms.
" 3876. Off Lahaina Light, Maui, 28–43 fathoms.
" 3962. Off Laysan Island, 16 fathoms.
" 3982. Off Nawiliwili Light, Kauai, 233–400 (?) fathoms.
" 3987. Off Hanamaulu, Kauai, 50–55 fathoms.

Station 4031. Off Diamond Head, Oahu, 27–28 fathoms.
" 4032. Off Diamond Head, Oahu, 27–29 fathoms.
" 4033. Off Diamond Head, Oahu, 28–29 fathoms.
" 4034. Off Diamond Head, Oahu, 14–28 fathoms.
" 4061. Off Kauhola Light, Hawaii, 24–83 fathoms.
" 4128. Off Hanamaulu, Kauai, 68–253 fathoms.
" 4146. Off Modu Manu, 23–26 fathoms.
" 4148. Off Modu Manu, 26–33 fathoms.
" 4150. Off Modu Manu, 71–160 fathoms.
" 4158. Off Modu Manu, 20–30 fathoms.
" 4164. Off Modu Manu, 40–56 fathoms.
One hundred and seventy-three specimens.

Clypeaster lytopetalus A. Ag. and Clark.

This species may be recognized at once by its small size and general resemblance to *scutiformis*, combined with short, broadly obovate petals, the anterior one widely open, and with a deep groove in each ambulacrum along the median suture, extending from the abactinal system nearly to the actinostome. The tubercles are less numerous than in *scutiformis* and the primary tubercles contrast decidedly with the miliaries. The poriferous zones are exceedingly narrow (less than one millimeter in width), and are of unequal length in the lateral petals. The sutures between the abactinal plates are quite distinct. The genital openings are very small. The test is very thin and the internal structure is remarkable for the great scarcity of pillars, of which there are one or two stout ones and one or two slender ones in each interradius, nearer the actinostome than the margin of the test; there are no needle-like internal projections such as are abundant in *scutiformis*. The larger specimen (St. 3962) is 33 mm. long, 26 mm. wide and 10 mm. high. The test is decidedly arched, with a deeply sunken actinostome, and is 5 mm. thick at the margin. The odd and the posterior petals are about 11 mm. long and 5–6 mm. broad near the tip, while the anterior lateral petals are equally broad, but only 8 mm. long. The odd petal has the poriferous zones 3 mm. apart at their distal ends. The color is dark yellowish-brown. The smaller specimen is about half as large and is bright reddish-brown. It is not impossible that this species will prove to be the young of *C. excelsior* Döderlein, from Japan, but the remarkable appearance of the petals distinguishes it from the only specimen of that species yet known.

Station 3936. Off Laysan Island, 79–130 fathoms.
" 3962. Off Laysan Island, 16 fathoms.
Two specimens.

Clypeaster leptostracon A. Ag. and Clark.

This species is nearly allied to *C. virescens* Döderlein from Japan, but differs in the outline of the test, the very narrow poriferous zones, the arrangement of the

internal pillars, and the color. It also resembles somewhat, young specimens of *C. humilis,* but is readily distinguished by the narrow poriferous zones, wide open petals, and very narrow interambulacra. The test is ovate, very flat and thin, with the actinostome little sunken and the petaliferous area abruptly, but slightly, elevated. The petals are short, broadly ovate, widely open distally and with very narrow poriferous zones. There are five genital openings. The primary spines are rather long and their tubercles contrast decidedly with the not very numerous miliaries. The walls of the test are thin and there are three or four concentric series of very flat, thin vertical pillars forming interrupted walls, occupying the distal fourth of the interior, much as in Laganum. But there is also, in each interradius, as in most true Clypeasters, a group of four or five pillars near the actinostome, and there are numerous, though minute, needle-like projections on the actinal floor. The specimens range from 6 to 38 mm. in length. The largest is 31 mm. broad and 7.5 mm. high; the test is only a little more than 3 mm. thick at the margin. The petals are subequal, 9 mm. long and a trifle over 5 mm. broad, but the poriferous zones are considerably less than a millimeter in width. The posterior lateral interambulacra are less than half as wide at the ambitus as the ambulacra on either side of them, though in smaller specimens they may be three-fourths as wide. In color the specimens vary from bright yellow, or reddish-yellow, to dirty purplish-white. The yellow specimens have a large number of rather indistinct, dusky blotches on the abactinal surface. These are arranged in pairs, four pairs in each ambulacrum and interambulacrum, and form four concentric circles around the petals, parallel to the margin of the test. In all the specimens there is more or less contrast in color between the ambulacra and interambulacra on the actinal surface.

Station 3823. Off Lae-o Ka Laau Light, Molokai, 78–222 fathoms.
" 3987. Off Hanamaulu, Kauai, 50–55 fathoms.
" 4046. Off Kawaihae Light, Hawaii, 71–147 fathoms.
" 4064. Off Kauhola Light, Hawaii, 63–107 fathoms.
" 4066. Off Ka Lae-o Ka Ilio Point, Maui, 49–176 fathoms.

Fifty-seven specimens.

LAGANIDAE Des. (Emended).

Laganum fudsiyama Död.

Laganum fudsiyama Döderlein, 1885. Arch. f. Naturg. Jahrg. **51**, Bd. 1, p. 104.

A large series of this species was collected. Most of them have the superficial appearance in miniature of specimens of *Clypeaster Ravenellii* A. Ag., the centre of the test is so considerably and abruptly elevated. The amount of elevation is, however, quite variable, ranging from 25 to 40 per cent of the long diameter. The smallest specimen measures 8 × 8 mm. and the largest 50 × 46. The color is usually green, but ranges from grayish-yellow to rich, deep green. Oftentimes the ambulacra, on the actinal side, are more or less colored with dark purplish-brown.

Station 3811. Off Honolulu Light, Oahu, 52–238 fathoms.
" 3838. Off Lae-o Ka Laau Light, Molokai, 92–212 fathoms.
" 4079. Off Puniawa Point, Maui, 143–178 fathoms.
" 4080. Off Puniawa Point, Maui, 178–202 fathoms.
" 4081. Off Puniawa Point, Maui, 202–220 fathoms.
" 4115. Off Kahuku Point, Oahu, 195–241 fathoms.
" 4122. Off Barber's Point Light, Oahu, 192–352 fathoms.

Four hundred and seven specimens.

Laganum solidum de Meij.

Laganum solidum de Meijere, 1904. Ech. Siboga-Exp., p. 121; Plate 1, Figs. 64, 66.

A number of bare tests, collected at several localities, differ from both the preceding and following species, in the far more numerous primary tubercles of the abactinal surface. They answer very nearly to the description and figures of *solidum*, and may, for the present at least, be referred to that species.

Station 3811. Off Honolulu Light, Oahu, 52–238 fathoms.
" 3859. Off Mokuhooniki Islet, Pailolo Channel, 138–140 fathoms.
" 3984. Off Nawiliwili Light, Kauai, 164–237 fathoms.
" 4101. Off Mokuhooniki Islet, Pailolo Channel, 122–143 fathoms.
" 4132. Off Hanamaulu, Kauai, 257–312 fathoms.

Sixteen specimens.

Laganum strigatum A. Ag. and Clark.

This species resembles *fudsiyama* in the short, narrow, open petals, the very narrow poriferous zones, and the moderately coarse tuberculation of the test. But it is easily distinguished from that species by the flatness of the test, the height of which rarely exceeds .20 of the long diameter; the distinctly visible sutures between the plates abactinally as well as actinally; and the color, which is purplish-gray or dull brown, with the sutures more or less plainly indicated by darker lines. There are usually five, but sometimes only four, genital pores. The anal opening is near the posterior margin of the test. A typical example is 30 × 29 mm. and only 6 mm. high.

Station 3811. Off Honolulu Light, Oahu, 52–238 fathoms.
" 3814. Off Diamond Head, Oahu, 42–284 fathoms.
" 3859. Off Mokuhooniki Islet, Pailolo Channel, 138–140 fathoms.
" 3863. Off Mokuhooniki, Islet, Pailolo Channel, 127–154 fathoms.
" 3876. Off Lahaina Light, Maui, 28–43 fathoms.
" 4099. Off Puniawa Point, Maui, 152–153 fathoms.

Nine specimens.

PETALOSTICHA Haeckel.

CASSIDULIDAE Agass.

ECHINONEIDAE Agass.

Micropetalon A. Ag. and Clark.

This genus is related to Echinoneus, which it resembles quite closely superficially. It is at once distinguished from that genus by the fact that the poriferous zones are flush with the test and the pores extend only from the abactinal system about half way to the ambitus. The anterior ambulacrum has about a dozen pairs of pores in each zone; the zones of the lateral ambulacra have about 15 pairs each; and the zones of the posterior pair have about 20. The zones are very narrow, close together at the abactinal system, diverge widely to below the ambitus and then converge somewhat to the actinostome. The primary tubercles are few in number, not at all sunken into the test, and are arranged in regular vertical series. Abactinally they have definite scrobicular circles of small secondaries, but these are more or less imperfect actinally. Glassy tubercles are minute and infrequent. Abactinal system as in Echinoneus. Genital openings four. Actinostome very oblique. Anal system very large and oblique. Primary spines rather long, nearly equal to width of anal system, slender and finely striated.

Micropetalon purpureum A. Ag. and Clark.

The single specimen collected is oval, flattened both above and beneath; it is 17 mm. long, 15 mm. broad, and 8 mm. high. The actinostome is little sunken and is 6 × 3 mm. The anal system is 6.75 × 3.75 mm. The genital openings are conspicuous. On each side of each ambulacrum, close to the poriferous zone, is a vertical series of about 14 primary tubercles, which extends nearly to the actinostome, but stops several millimeters from the abactinal system. Between these two series, are two other series running from just above the ambitus nearly to the actinostome, and in the posterior ambulacra there are two more rows between the ambitus and the mouth. In each interambulacrum, there is a series of 14 or 15 tubercles on each side, extending from abactinal system to actinostome, and from two to four others extend greater or less distances above and below the ambitus. The color of the test is dirty-whitish above, becoming purple actinally; the abactinal system, poriferous zones, anal system, and actinostome are rich purple; the spines and tubercles are white.

Station 3847. Off Lae-o Ka Laau Light, Molokai, 23–24 fathoms.

SPATANGIDAE Agass.

PALEOPNEUSTIDAE A. Ag.

Phrissocystis multispina A. Ag. and Clark.

From an unknown station there are a large number of fragments of at least two, and possibly three, individuals of a species of Phrissocystis, which must have been of very large size, probably from 100–150 mm. in length. They are of a rich red-brown color and carry long spines with a reddish tinge. This species resembles *P. aculeata* A. Ag. in having no subanal fasciole and in the arrangement of the abactinal system and the ambulacra. It appears to differ from that species, not only in color, but in the much larger number of primary tubercles on the abactinal plates (8–12 instead of 4–8) and in the very large actinostome, which in one individual is 35 × 16 mm.

Meijerea excentrica A. Ag. and Clark.

This species is very similar to Phrissocystis, but has a well-developed subanal fasciole. As Döderlein (1906) has suggested, this difference necessitates a new genus which he has called Meijerea, with *Phrissocystis humilis* de Meijere as the type species. The Hawaiian specimen is evidently not *humilis*, as it is much flatter and more heart-shaped, with the abactinal system considerably posterior to the middle of the test. The subanal fasciole is also different; it encloses an open rectangular area, 4.5 mm. wide, with the base 24 mm., and the sides 10 mm. in length. The test is 74 mm. long, 60 mm. wide and only 17 mm. high, and the abactinal system is 39 mm. from the anterior edge. The color is light brown, with whitish primary spines.

Station 4039. Off Kawaihae Light, Hawaii, 670–697 fathoms.

One specimen.

Pycnolampas A. Ag. and Clark.

This genus is established for some delicate little Spatangoids, which, although apparently immature, do not appear to be the young of any known species, and seem to require a new genus for their reception. It is most nearly allied to Homolampas, but differs from that genus in the entire absence of any anterior furrow or depression, and in the subpetaloid character of the posterior ambulacra. The test is ovate, rather flat anteriorly, higher posteriorly, and is thin and fragile. There are a very few large primary spines in the anterior and lateral interambulacra, abactinally, but neither they, nor those of the actinal surface, have sunken scrobicular circles or show any pits (as in Lovenia) on the interior of the test. Abactinal system compact. Ocular plates conspicuous. Anterior ambulacrum indistinct, not at all depressed, and with few, minute pores. Poriferous zones of the other ambulacra evident, those of the posterior ambulacra especially, tending to become petaloid. Subanal and peripetalous fascioles present, distinct but narrow. No genital openings are visible.

Pycnolampas oviformis A. Ag. and Clark.

The specimens collected range from 15 to 22 mm. in longitudinal diameter. The largest is 17 mm. wide, 9 mm. high anteriorly, and 10 mm. high posteriorly. The peripetalous fasciole is nearly circular, somewhat pointed behind, 14 × 12 mm. The color is pearly white with a purplish tint on the abactinal system; the fascioles are brown and the spines are yellowish-white.

Station 3838. Off Lae-o Ka Laau Light, Molokai, 92–212 fathoms.
" 3890. Off Mokapu Islet, Molokai, 71–283 fathoms.
" 4044. Off Kawaihae Light, Hawaii, 198–233 fathoms.

Five specimens.

SPATANGINA Gray.

Spatangus paucituberculatus A. Ag. and Clark.

This species is most nearly related to *S. Lütkeni* A. Ag., but is quite different from that species. The test is very broad and flat and obliquely truncated posteriorly, sloping towards the actinostome. The groove of the anterior ambulacrum is very deep. On each side of it are a number of primary tubercles; in the lateral interambulacra the number of primary tubercles is 2, 1, or 0, and in the posterior interambulacrum there are not more than 9 or 10. The anal system is small and nearly circular. The actinal surface is much as in *Lütkeni*. The largest specimen is 78 mm. long, 74 mm. wide, and only 40 mm. high; the anterior furrow is 5 mm. deep and 13 mm. wide, at the ambitus. The color is purple, with white tubercles; primaries and secondaries silvery-white becoming purple at the base; miliary spines purple.

Station 3863. Off Mokuhooniki Islet, Pailolo Channel, 127–154 fathoms.
" 3865. Off Mokuhooniki Islet, Pailolo Channel, 256–283 fathoms.
" 4096. Off Mokuhooniki Islet, Pailolo Channel, 272–286 fathoms.
" 4097. Off Mokuhooniki Islet, Pailolo Channel, 286 fathoms.
" 4116. Off Kahuku Point, Oahu, 241–282 fathoms.

Twelve specimens.

Gymnopatagus Död.

Gymnopatagus Döderlein 1901. Zool. Anz. Bd. **23**, p. 22.

This genus was established by Döderlein for an interesting Spatangoid, taken by the "Valdivia" off the east coast of Africa, related to Eupatagus but having a decided furrow for the anterior ambulacrum. The "Albatross" has collected among the Hawaiian Islands two species of large Spatangoids, which are of special interest because they are evidently connecting links between these two genera. In one of them the anterior furrow is quite distinct, while in the other it is barely indicated, and yet the two are obviously congeneric. In both species the anterior poriferous zones of the lateral ambulacra are much narrower than the posterior zones, and are almost rudimentary near the abactinal system; a condition not

noted in either Eupatagus or Gymnopatagus. As the general appearance of these Hawaiian Spatangoids is decidedly more like Gymnopatagus than like any known species of Eupatagus, we place them for the present in the former genus, but it is an open question whether the two genera can be separated.

The Hawaiian species are of further interest from the remarkable diversity exhibited by the peripetalous fasciole, which is seldom a single, simple band. In one specimen there are several narrow but distinct fascioles across the anterior ambulacrum, within and parallel to the peripetalous fasciole. In another individual, a conspicuous branch arises from the posterior part of the fasciole and runs for several centimeters beside but slightly diverging from the main band, and finally ends abruptly. In other individuals, the lateral portions of the fasciole consist of two parallel bands, more or less connected with each other. Although the complexity of the arrangement is never as great as in *Macropneustes spatangoides* A. Ag., these fascioles at once suggest that West Indian species.

Gymnopatagus pulchellus A. Ag. and Clark.

The specimens range from 57 to 90 mm. in length. The largest is 70 mm. wide and 33 mm. high; it is widest and highest just back of the abactinal system. The anterior ambulacrum is apetaloid and scarcely sunken. There are no primary tubercles in the posterior interambulacrum but there are 35–40 in the lateral interambulacra, within the fasciole, arranged in four or five rows parallel to it; there are also about 20 similar tubercles in each of the anterior interambulacra. These tubercles carry long, slender, brownish-white spines, some of which are 30 mm. in length. The posterior petals are very long, about .40 of the length of the test. The smallest specimen is bright rose color above and nearly pure white beneath, though the spines all have a brownish cast. Larger specimens are less rosy and more fawn-color. The test of the largest is nearly uniform fawn-color, with the long spines almost white.

Station 3810. Off Honolulu Light, Oahu, 53–211 fathoms.
" 3811. Off Honolulu Light, Oahu, 52–238 fathoms.
" 4045. Off Kawaihae Light, Hawaii, 147–198 fathoms.

Six specimens.

Gymnopatagus obscurus A. Ag. and Clark.

This species differs from the preceding in the conspicuous groove for the anterior ambulacrum, the presence of 6–9 primary tubercles in the posterior interambulacrum, the higher and more ovate test, and fewer tubercles in the lateral interambulacra. The specimens are all of about the same size and measure 85 mm. in length, by 70 mm. in width and 35 mm. in height. The test is widest at about the middle of the posterior pair of petals, which are nearly as long as in the preceding species. The primary spines are only about 20 mm. long. The color is dull brown, the spines somewhat lighter.

Station 3912. Off Diamond Head Light, Oahu, 310–334 fathoms.
" 4081. Off Puniawa Point, Maui, 202–220 fathoms.

Eight specimens.

Lovenia grisea A. Ag. and Clark.

This species is near *L. gregalis* Alcock, but is much more heart-shaped, flatter, and decidedly narrower posteriorly. The test is densely covered with spines, and the lateral ambulacra are quite different from those of *gregalis*. On the actinal surface, the bare posterior ambulacra are not nearly so wide as in de Meijere's (1904) figure of *gregalis*. Unfortunately the single specimen is so badly injured that there is no trace of the abactinal system and internal fasciole; the subanal fasciole is also injured. There is no anterior lateral fasciole. The petals are well-developed, nearly closed and pointed, with the poriferous zones almost straight and scarcely sunken. The specimen is 81 mm. wide and only 26 mm. high; it must have been about 90 mm. in length. The anterior lateral ambulacra are only 4 mm. wide at a distance of 15 mm. from the ambitus, but at the ambitus they are 12 mm. The color is light olive gray.

Station 4080. Off Puniawa Point, Maui, 178–202 fathoms.

Pseudolovenia A. Ag. and Clark.

This genus resembles Lovenia very closely when the specimens are covered with spines, but when the abactinal surface is denuded the difference in the posterior ambulacra is very striking. These ambulacra are not petaloid, the poriferous zones are flush with the surface of the test, and, though slightly converging at first, diverge towards the ambitus, the petals becoming more and more open, while the pores of a pair come closer together until, below the ambitus, there are only single pores. The anterior lateral ambulacra are subpetaloid with the poriferous zones flush. Fascioles, tubercles, and spines much as in Lovenia.

Pseudolovenia hirsuta A. Ag. and Clark.

The test is distinctly heart-shaped with an evident groove for the anterior ambulacrum. It is densely covered, especially in the young, with slender miliary spines 2–4 mm. long. The abactinal system is only about one-third of the length, from the anterior extremity, and is more anterior still in very young individuals. The test is highest at or behind the abactinal system. The number of large primaries increases with size; there are 2 or 3 in each anterior interradius and from 3 to 8 in each lateral interradius, in specimens under 50 mm. in length. In larger specimens there may be as many as 6 in front and 12 on the side. The largest specimen is badly damaged at the posterior extremity, but is 54 mm. wide and must have been nearly 65 mm. long; it is a trifle over 22 mm. high. Smaller specimens are relatively higher and narrower. In the best preserved specimen, which is 60 × 51 mm., the posterior ambulacra from the internal fasciole to the margin measure 33 mm.; the interporiferous area is 3 mm. wide at the fasciole, 2.25 mm. wide 13 mm. from the fasciole, and 5 mm. wide at the ambitus. The color is gray, becoming dirty white in the largest specimen. Young specimens are more nearly cream-color. The primary spines are white, and in the largest specimen are from 30 to 37 mm. long.

Station 3836. Off Lae-o Ka Laau Light, Molokai, 238–255 fathoms.
" 3839. Off Lae-o Ka Laau Light, Molokai, 259–266 fathoms.
" 3865. Off Mokuhooniki Islet, Pailolo Channel, 256–283 fathoms.
" 3920. Off Diamond Head Light, Oahu, 265–280 fathoms.
" 4028. Off Ukula Point, Kauai, 444–478 fathoms.
" 4036. Off Kawaihae Light, Hawaii, 687–692 fathoms.
" 4083. Off Puniawa Point, Maui, 238–253 fathoms.
" 4122. Off Barber's Point Light, Oahu, 192–352 fathoms.

Eighteen specimens.

BRISSINA Gray.

Rhinobrissus placopetalus A. Ag. and Clark.

The specimens are small and immature, but the shape of the test and the large petals flush with the test distinguish this species from any previously known. The test of the largest is 14 mm. long and 12 mm. wide, lowest anteriorly and sloping steadily upward to the posterior extremity, where it is highest. It is widest at the abactinal system, which is just over the mouth. At this point the vertical height is 8 mm., while at the posterior end it is 10 mm. The anterior ambulacrum is flush, with few very minute pores. The other ambulacra are distinctly petaloid, scarcely sunken, and are subequal, 4 mm. long with 13 or 14 pairs of pores. The peripetalous, anal, and subanal fascioles are all well developed. The color is light yellowish-brown.

Station 4146. Vicinity of Modu Manu, 23–26 fathoms.
" 4160. Vicinity of Modu Manu, 31–39 fathoms.

Three specimens.

Brissopsis luzonica A. Ag.

Kleinia luzonica Gray, 1851. Ann. Mag. Nat. Hist. (2) 1, p. 133.
Brissopsis luzonica A. Agassiz, 1872. Rev. Ech. Pt. 1, p. 95.

A good series of this species is found in the collection, but owing to the fragility of the test (see Döderlein, 1906) most of them are more or less badly broken.

Station 3836. Off Lae-o Ka Laau Light, Molokai, 238–255 fathoms.
" 3839. Off Lae-o Ka Laau Light, Molokai, 259–266 fathoms.
" 4044. Off Kawaihae Light, Hawaii, 198–233 fathoms.
" 4083. Off Puniawa Point, Maui, 238–253 fathoms.
" 4131. Off Hanamaulu, Kauai, 257–309 fathoms.
" 4132. Off Hanamaulu, Kauai, 257–312 fathoms.

Twenty-four specimens.

Brissopsis Oldhami Alcock.

Brissopsis Oldhami Alcock, 1893. Jour. Asiat. Soc. Bengal, **62**, Pt. 2, No. 4, p. 6 (174).

Our specimens agree exactly with Alcock's description, but as he gives no measurements and his figures are of a small specimen, it is not easy to see why he

did not regard the Indian form as *luzonica*. Comparison of the Hawaiian specimens of *Oldhami* and *luzonica* reveals several apparently constant differences which warrant their separation. In *luzonica*, the breadth of the test is usually .80–.85 of the length, though it may be more; in *Oldhami* it is over .90. In *luzonica* the width of the area enclosed by the peripetalous fasciole is about .50 of its length, rarely more than .55; in *Oldhami* it is .60–.70. In *luzonica* the height of the subanal fasciole is about .50 of its horizontal breadth; in *Oldhami* it is rarely over .40. The actinostome is more deeply sunken and the labrum is more prominent and more nearly pointed in *Oldhami* than in *luzonica*. The petals are slightly broader and the lateral petals are a little longer, and are more noticeably depressed below the fasciole, in *Oldhami*. It is evident therefore that this species is nearer *lyrifera* than *luzonica* is, but it agrees closely with the latter in color and fragility of the test. The largest specimens are about 50 × 45 mm.

Station 3824. Off Lae-o Ka Laau Light, Molokai, 222–498 fathoms.
" 3826. Off Lae-o Ka Laau Light, Molokai, 371–430 fathoms.
" 3839. Off Lae-o Ka Laau Light, Molokai, 259–266 fathoms.
" 3842. Off Lae-o Ka Laau Light, Molokai, 495–506 fathoms.
" 3863. Off Mokuhooniki Islet, Pailolo Channel, 127–154 fathoms.
" 3892. Off Mokapu Islet, Molokai, 328–414 fathoms.
" 3908. Off Diamond Head Light, Oahu, 304–308 fathoms.
" 3912. Off Diamond Head Light, Oahu, 310–334 fathoms.
" 3916. Off Diamond Head Light, Oahu, 299–330 fathoms.
" 3917. Off Diamond Head Light, Oahu, 294–330 fathoms.
" 3918. Off Diamond Head Light, Oahu, 257–294 fathoms.
" 3992. Off Mokuaeae Islet, Kauai, 528 fathoms.
" 3997. Off Ukula Point, Kauai, 418–429 fathoms.
" 4028. Off Ukula Point, Kauai, 444–478 fathoms.
" 4132. Off Hanamaulu, Kauai, 257–312 fathoms.

Thirty-seven specimens.

Brissopsis circosemita A. Ag. and Clark.

We have given this name to a small Spatangoid, of which there is only a single specimen, and that a bare test 17 mm. long, 14 mm. wide, and 11 mm. high. The posterior extremity is truncate vertically. The plastron is slightly keeled posteriorly. The labrum is nearly straight, and the actinostome is scarcely sunken. The peripetalous fasciole and the petals are similar to those of a young *luzonica*, but the subanal fasciole is unique. It is quite small and nearly circular, 5 mm. in transverse diameter and 5.25 mm. vertically. A conspicuous branch arises from the upper portion, on each side of the anal system, and runs to the posterior portion of the peripetalous fasciole, which it joins in the posterior ambulacrum. The two branches thus enclose the anal system, but are not very near to it. While such anal fasciolar branches are not uncommon in Brissopsis, they are particularly distinct and complete in this specimen. Only three ambulacral plates enter the subanal fasciole on each side. The abactinal system is very compact

and the genital opening in the right anterior plate is much smaller than the other three.

Station 4070. Off Puniawa Point, Maui, 45–52 fathoms.

Brissus carinatus Gray.

Spatangus carinatus Lamarck, 1816. Anim. s. Ver. **3**, p. 30.
Brissus carinatus Gray, 1825. Ann. Phil. **10**, p. 9.

There is a bare test, 55 × 42 mm., from Laysan Island, which is undoubtedly this species. We also refer to Brissus, and probably *carinatus*, a young Spatangoid about 10 mm. long, in which the petals are not quite perfect and are little sunken, while the subanal fasciole is disproportionately large. It was taken at Station 4147, vicinity of Modu Manu, in 26 fathoms.

Metalia maculosa A. Ag.

Echinus maculosus Gmelin, 1788. Linn. Sys. Nat., p. 3199.
Metalia maculosa A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 144.

A small fragment of the right posterior ambulacrum and part of the posterior interambulacrum of a large Spatangoid from Station 4149 is evidently from the test of one of this species.

Station 4149. Off Modu Manu, 33–71 fathoms.

Aceste Wyv. Thom.

Aceste Wyville Thomson, 1877. Voy. Chall. Atlantic, **1**, p. 376.

There are a few good specimens, and fragments of several others, of this genus, but none of them seem to be *bellidifera*, the only species hitherto known. They all agree in having the posterior extremity nearly vertical and the anterior furrow deep and with nearly vertical sides. The actinal plastron is perfectly flat and does not project either in front of or below the mouth. In these particulars the specimens are evidently different from *bellidifera*, and the difference is emphasized when the relative length of the plastron is noted. In *bellidifera* the plastron measures from the posterior edge of the tuberculated portion to the mouth, only about .65 of the length of the test, while in the Hawaiian specimens it is considerably more than .75. Not only do these specimens differ from *bellidifera*, but those from the west end of Molokai are obviously different from those taken off the west coast of Hawaii, and we are accordingly obliged to recognize two new species of *Aceste*.

Aceste ovata A. Ag. and Clark.

The points in which this species differs from *bellidifera* have already been stated. The largest specimen is 19 × 15 mm. and the others are nearly as large. The test is broadly ovate, rounded behind. It slopes backward slightly from the posterior edge of the fasciole for a very short distance, and is then vertically truncated. The fasciole is nearly oval and not angular, though it is somewhat pointed behind. The color of these specimens is light brown, with the fasciole a somewhat darker brown.

Station 3836. Off Lae-o Ka Laau Light, Molokai, 238–255 fathoms.
" 3839. Off Lae-o Ka Laau Light, Molokai, 259–266 fathoms.
Six specimens.

Aceste purpurea A. Ag. and Clark.

This species differs from the preceding in the shape of the fasciole and in color. The fasciole is somewhat angular, though the angles are rounded, and the enclosed area is abruptly widened just behind the middle of its course. The general color is pale purple, with the fasciole a very deep purple. A small specimen, only 13 mm. long, from St. 3898, has this same coloration, and, although the fasciole has no prominent angles, is evidently this species. The largest specimen is nearly 22 mm. long.
Station 3898. Off Mokuhooniki Islet, Pailolo Channel, 258–284 fathoms.
" 4041. Off Kawaihae Light, Hawaii, 253–382 fathoms.
Three specimens.

Schizaster japonicus A. Ag.

Schizaster japonicus A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 212.

A very small Spatangoid, only a trifle over 8 mm. in length, is evidently a Schizaster, and in the appearance of the petals is more like *japonica* than it is like any other described species.
Station 4064. Off Kauhola Light, Hawaii, 63–107 fathoms.

Periaster maximus A. Ag. and Clark.

Although there is in the collection only a single fragment of this Spatangoid, it shows such great size for a Periaster and such unique features, we feel justified in giving it a name. The fragment is the posterior left-hand quarter, approximately, of the abactinal part of the test and includes the left posterior petal and most of the right one too. The anal system is also present, but no part of the test below it. A perfectly bare band, two millimeters wide, runs from the posterior part of the peripetalous fasciole, in the median line, straight to the anal system. This band is nearly 50 mm. long. The petals are 18 mm. long by 6 mm. wide. The anal system is 11 mm. across horizontally. The shape of this species was apparently more like *limicola* than like *tenuis*, and if we calculate its dimensions by proportion, comparing it with a specimen of *limicola* 65 mm. long, we find that, unless the shape was very different from that species, this individual must have been about 110 mm. long, 105 mm. wide, and 95 mm. high. The color is very light brown. There are some large primary tubercles in the interambulacra, within the fasciole.
Station 4130. Off Hanamaulu, Kauai, 283–309 fathoms.

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A COLLECTION OF SPHECIDAE FROM ARGENTINE.

By H. T. Fernald.

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No. 9. — *A Collection of Sphecidae from Argentine.*

By H. T. Fernald.

The Sphecidae here reported upon form a part of a general collection of several orders of insects made by Prof. W. M. Davis of Harvard University during the years 1871 to 1873, while a member of the staff at the Astronomical Observatory at Cordova, Argentine. Professor Davis, although much occupied by his regular duties, was interested in the fauna and flora of the region where the Observatory was located, and devoted considerable time to making collections and observations on the insects found there, and the specimens, together with remarkably fine records of his observations, are now at the Museum of Comparative Zoölogy.

The Sphecidae in the collection are represented by seventy-seven specimens, and include several forms apparently hitherto unknown to science. An opportunity to study these specimens has been obtained through the kindness of the Museum authorities. To Professor Davis I am greatly indebted for assistance received during the preparation of this paper.

Pelopaeus figulus Dahlb.

Two female, ten male specimens. Length, 15–22 mm.

Chlorion (Chlorion) cyaniventris (Guer.).

Seven female, five male specimens. Length, 16–24 mm.

Chlorion (Chlorion) hemiprasinum (Sichel).

One female, four male specimens. Length, 19–25 mm.

These specimens differ somewhat as regards color distribution from any of the varieties mentioned by Kohl. The head, thorax, median segment, petiole, coxae, trochanters, and more or less of the femora are blue with a greenish reflection, so strong in some places that the color there might be stated as green with a bluish reflection. The antennae are black except near their tips, the last three or four segments being partly red. The entire abdomen beyond the petiole, the outer

ends of the femora, and the tibiae are red: the tarsi are dark brown with here and there a reddish tinge. Wings uniformly deep fuliginous, with a bluish, or at some angles a greenish, reflection.

This form seems to come nearest to Kohl's variety *nobilitatum.*

Chlorion (Priononyx) striatum (Smith).

Eight female specimens. Length, 18–26 mm.

Chlorion (Priononyx) thomae (Fab.).

Three female specimens.

Chlorion (Priononyx) simillimum, sp. nov.

? *Sphex neoxenus* Kohl, ♀, Ann. natur. Hofmus. Wien, 1890, **5**, p. 363.
? *Sphex ommissus* Kohl, ♂, Ann. natur. Hofmus. Wien, 1890, **5**, p. 364.

Female. Black, without pubescence. Wings uniformly fuliginous, with a greenish reflection as far as the outer ends of the cells, the outer margins with less reflection, and this rather violet than green.

Head quite large, quadrate when viewed from above. Central portion of the clypeus strongly swollen; the anterior margin somewhat reflexed and with a pronounced central notch in a slight depression; its surface glistening, not closely punctured, and bearing black hairs of medium size. Frons considerably excavated near and above the antennal insertions, rather more closely and finely punctured than the clypeus, and with traces of transverse striations along the sides of the well-marked frontal suture from the antennae about halfway to the median ocellus. Ocellar area enclosed by three impressed lines, the posterior line arched backward and crossed by the frontal suture, which is present between and behind the ocelli. The lateral impressed lines extend behind the ocelli a short distance and end just in front of, and lateral to, a small macrochaeta on either side. Distance between the lateral ocelli less than between the ocelli and the eyes; median ocellus much larger than the lateral ones. Upper part of the frons and the vertex minutely, not closely, punctured. Cheeks above more than half the width of the eye, but narrowing quickly downward; with scattered punctures and hairs, the latter larger and longer below. Inner margins of the eyes parallel. Antennae black, the scape with a ferruginous tinge below; the filament somewhat grayish sericeous: first filament segment nearly two-thirds as long as the second and third together. Mandibles long, stout, black, tinged with ferruginous at the tip and along the middle of the lower (outer) margin; with numerous aciculations and black hairs.

Thorax black. Collar rising quite abruptly from the neck, its dorsal edge quite broad from front to rear, rounded, and also evenly rounded from side to side for some distance, then quickly bending downward, the sides bearing faint striations. Surface of the anterior face and dorsal edge of the collar somewhat glistening, sparsely punctured. Sides of the neck and collar, and the upper part of the prothoracic lobe, obliquely striate except a small tubercle anterior to the upper part of the prothoracic lobe, which is smooth and glistening. The prothorax below the lateral sutures is coarsely punctured, and near the coxae has a few faint transverse striations. Margin of the prothoracic lobe fringed with short brown hairs.

Mesonotum rising but little above the top of the collar, with a pronounced median depression nearly reaching the posterior edge of the plate, which is strongly transversely striate, the striations being slightly oblique in front and markedly so near the middle line behind. Scattered punctures are also present. Scutellum considerably higher in the middle than the mesonotum, with a median depression forming a pair of quite smooth, glistening projections, which are quite noticeable and almost large enough to be described as bituberculate. Sides of the scutellum striate and closely punctured. Postscutellum narrow, with no median depression, closely punctured. Dorsum of median segment long, with a faint median depression and its lateral lines depressed; its surface closely, transversely striate, and bearing numerous quite long, black hairs. Posterior end and sides similarly striate and with similar hairs, the striations extending down across the metapleura. Mesopleura and mesosternum coarsely and closely punctured except in front of the coxae. Petiole short, rather stout, almost straight, two-thirds as long as the hind metatarsus, equal to the second hind tarsal segment in length, with small, scattered punctures.

Abdomen black but with a faint ferruginous tinge, rising high and almost perpendicular from the petiole, smooth and glistening. Stigma of the second abdominal plate close to the anterior margin. Dorsal plate minutely, sparsely punctured, some of the punctures forming a row on each side of the middle line, nearly parallel to and a little distance in front of, the posterior margins of the plates. A similar arrangement of the punctures occurs below, except that there they form a narrow band instead of a row. Last dorsal and ventral plates with scattered, coarser punctures, and a few black hairs.

Wings uniformly fuliginous, with a slight greenish reflection except outside the cells, where it is very faint or absent. First and second transverse cubital veins of the fore wing each with a bulla near the cubital. Radial cell rather short, its end rounded. Cubital vein almost obsolete beyond the third cubital cell. A bulla is present in the transverse cubital vein of the hind wing. Tegulae black, glistening, with a few scattered punctures.

Legs black, very faintly tinged with ferruginous, the tarsi and the middle and hind tibiae somewhat grayish sericeous. Fore metatarsus with eight comb teeth, the first shorter than the others. Posterior face of hind tibiae coarsely brown sericeous. Claws with three teeth evident and one (the inner) microscopic. Tips of the claws ferruginous.

The male differs as follows: — Clypeus and frons with traces of silvery pubescence. Clypeus elongated, its anterior margin slightly, broadly excavated, not reflexed. Inner margins of eyes very slightly approaching downward. Frontal suture not developed in the ocellar area. First and second segments of the antennal filament short, together a very little longer than the third. Distance between the lateral ocelli about equal to that between them and the eyes. Cheeks retaining their greatest width well down before narrowing. Mandibles with less of the ferruginous tinge.

Dorsal edge of the collar and sides of the mesonotum with faint traces of short silvery hairs suggesting pubescence there in fresh specimens. Scutellar projections less marked than in the female. Sixth ventral abdominal plate rather narrowly, deeply excised behind, and covered with short brownish hairs. Claws with four teeth, the inner one, though smaller than the others, being perceptible in favorable specimens.

Length. — Female, 19 mm.; males, 14–15 mm.

Described from one female and two males captured at Cordova, Argentine.

The female comes very close to *neoxenum* Kohl, differing from it, according to the description, in that the abdomen is not red but black with a reddish tinge, the face is not pubescent, the mesonotum is not glistening but striate, the reflection of the wings is not violet or steel blue but greenish, and the length is three millimeters greater than in Kohl's specimen. Remembering, however, what great color variations are present in this group, the difference in the mesonotum seems to be the only one of importance.

The sole specimen of *neoxenum* bore the locality record Vancouver Island, but Kohl is of the opinion that this is an error and that it came from Chili. I have seen large collections of Sphecidae from the northwestern Pacific Coast, but have met with nothing like *neoxenum;* and as the specimen before me from Argentine so closely resembles Kohl's species, I am also of the opinion that *neoxenum* is a South American insect, and that with a longer series for study *simillimum* may prove to be only a color subspecies.

The males agree quite closely with *ommissum* Kohl, except in the color of the abdomen and in the presence of an excised margin on the sixth ventral abdominal plate. I feel confident that they are the same species as the female here described, and that they are likely to prove to be *ommissum.*

If all these assumptions should prove correct, the species will be known as *Chlorion* (*Priononyx*) *neoxenum* (Kohl).

Chlorion (Pseudosphex) pumilo (Tasch.).

Sphex (*Pseudosphex*) *dolichoderus* Kohl, Ann. natur. Hofmus. Wien, 1890, **5**, p. 370.

One female specimen. Length, 12 mm.

Kohl states that *dolichoderus* is very similar to *pumilo*, but separates them on the ground that the latter has three cubital cells, the first receiving the first recurrent, and the second the second recurrent, while in *dolichoderus* the first transverse cubital vein has disappeared so that both recurrent veins join the elongated first cubital cell. In *pumilo* the petiole is nearly as long as the hind metatarsus, while in *dolichoderus* it is only two-thirds the length of this segment. In the former it is as long as the first, second, and half of the third segments of the antennal filament taken together, while in the latter it is scarcely equal to that of the first and second.

In the specimen before me the venation of the right fore wing is that of *pumilo*, while that of the left is that of *dolichoderus*, except that there is a partial first transverse cubital vein extending backward a short distance from the radial cell before it disappears. The length of the petiole is four-fifths that of the hind metatarsus, thus placing this specimen as an intermediate between the two species under consideration, in that regard; and as only the first segment of the filament is present in each antenna, the third distinction cannot be tested.

Kohl's *dolichoderus* came from Chili; Taschenberg's *pumilo* came from Mendoza, close to the Andes on their eastern side; while the specimen now under consideration was taken less than three hundred miles farther east and but a little farther north.

From these facts it seems certain that the distinctions between *dolichoderus* and *pumilo* represent individual variations merely, and that the former must be considered a synonym of *pumilo*.

Chlorion (Proterosphex) argentinum (Tasch.).

Two female specimens. Length, 22–24 mm.

These specimens hardly agree with the descriptions of this species in all regards. The differences are mainly those of color distribution, however, and it is doubtful if they are of great importance.

The enlarged portion of the first dorsal abdominal plate is black except a narrow posterior and lateral strip of red. On each side of the second dorsal plate is a half-moon shaped black spot, its curved side being posterior. The fourth dorsal plate is black except for a narrow red posterior margin which on the middle line extends into the black in the form of a V. All the other parts of the dorsal plates are red. The surface beneath is red except for two black, rather vaguely limited black bands on the first ventral plate which extend outward and backward from the petiole.

In his key leading to this species Kohl describes the tibiae as suddenly thickened at the end on the inner side. This is somewhat misleading, as, though the end is thickened, it is not suddenly so, his Figure 18 being a better representation than his Figure 20.

Chlorion (Proterosphex) davisi, sp. nov.

Female. Black; wings hyaline except at tip and near base; large, robust.

Head large, not quadrate from above, the frons being depressed between the eyes and the cheeks sloping sharply toward the neck. Clypeus and frons densely covered with pale yellow pubescence and long hairs of the same color. Clypeus somewhat arched, its anterior margin evenly rounded except for a small truncated central lobe. Frons quite deeply sunken between the eyes, pubescent nearly to the ocelli, and where bare, showing scattered punctures of medium size. Ocellar area rather faintly limited by depressed lines, the frontal suture evident from the pubescence to the anterior ocellus. Vertex narrow from front to rear, bearing scattered, long brown hairs. Distance between the lateral ocelli slightly greater than between them and the eyes. Cheeks about half the width of the eye, widest opposite the middle of the neck and narrowing quickly above and below, glistening, with scattered punctures, thicker below, where there are also numerous long dark brown hairs. Inner margins of the eyes about parallel. Antennae black, grayish or brownish sericeous beyond the first filament segment, the scape tinged with ferruginous beneath, with a trace of yellowish pubescence at the base and short dark brown hairs on the inner side and tip. Mandibles quite stout, black, with a faint

ferruginous tinge; with a row of aciculations on the outer edge and bearing an irregular fringe of quite long black hairs. Terminal tooth of each mandible extending some distance beyond the base of the other.

Thorax. Neck short. Anterior face of collar very flat, rising at right angles to the neck, its surface sparsely pale yellow pubescent. Dorsal edge of collar very narrow, evenly rounded, closely appressed against the mesonotum. Sides of the collar glistening in front of the prothoracic lobe, and excavated, forming quite a sharp vertical ridge anteriorly. Prothoracic lobe with a few scattered punctures and brown hairs, and with a trace of golden pubescence behind. Prosternum sparsely punctured, bearing quite long brown hairs. Mesonotum rising somewhat sharply at first above the collar, with a faint, short, anterior median depression; its surface evenly but not closely covered with punctures of medium size, pale sericeous at certain angles, and bearing a few short brown hairs; its lateral margin somewhat reflexed from in front of the tegulae to the posterior corners. Scutellum rather broad from front to rear, and quite flat, its surface somewhat glistening, and punctured about like the mesonotum, with a slight median depression behind. Postscutellum narrow, strongly bituberculate, minutely punctured. Dorsum of the median segment closely, transversely striate, the striations being coarser at the sides behind the stigma, but not extending beyond the limits of the dorsum; its surface quite thickly covered with rather short, erect, brown hairs. Fovea broadly crescentic. Posterior end of the median segment forming nearly a right angle with the dorsum; its surface granular, and bearing quite a thick clothing of long brown hairs. Toward the sides there are faint traces of striations above, but the surface for some little distance behind the stigmatal groove is smooth except for minute punctures, and somewhat glistening. Stigmatal groove running forward some distance from the hind coxae, then turning sharply upward to the stigma close behind a pronounced, narrow, vertical ridge, which extends down from the front of the stigma to a point a little below the bend of the stigmatal groove. Meso- and meta-pleura rather closely and minutely punctured, quite thickly covered with short brown hairs. Petiole black, with a faint reddish tinge, short, straight, a little shorter than the second hind tarsal segment, or the first filament segment, one-third longer than the second filament segment; its surface minutely punctured, and bearing short brown hairs.

Abdomen quite long in proportion to its width, rather pointed behind, black with a dull reddish tinge, particularly on the sides and beneath, whitish or grayish sericeous, particularly on the second and third dorsal plates. Stigmata reddish. Dorsal plates with minute scattered punctures, except the last two, which are quite coarsely punctured and bear a few reddish brown hairs. Beneath, with a number of quite long brown or reddish brown hairs on the last plate.

Wings hyaline, except on the outer margin of the fore wing from the end of the radial cell back to the end of the subdiscoidal vein, and at the base, all of the costal cell and the greater portion of the median, submedian, and anal cells, which are deep brown. The base of the hind wing is similarly colored. Cubital vein obsolete beyond the third cubital cell in the fore wing. That of the hind wing present for a short distance beyond the transverse cubital vein. Radial vein of the hind wing arched strongly forward beyond the transverse cubital. Transverse median vein nearly straight, joining the median at more than a right angle. Tegulae black, with a reddish tinge behind, with a trace of sericeous at some angles.

Legs dark reddish brown to black. Fore metatarsi with eleven comb teeth more than half the length of the segment, the first one shorter. Inner contour of hind tibia straight. Otherwise the legs have no differential characters.

Length, 29 mm. Expanse of wings, 44 mm.

Described from one female specimen captured at Cordova, Argentine.

This species in some regards seems to resemble *Chlorion fuliginosum*, *C. servillei*, and *C. nitidiventris*, but comparison with specimens of the first two species shows numerous differences, and the description of the third fails to agree with it in a number of points.

I take great pleasure in naming this species for Prof. W. M. Davis of Harvard University.

Sphex nigrocinctus, sp. nov.

Female. Head almost all black; thorax, median segment, first segment of petiole, coxae, and trochanters entirely black. The other segments of the legs, and the abdomen, except the fourth segment, red. Wings hyaline, with a faint yellowish shade near the base; slightly fuliginous along the outer margin.

Head large, quite quadrate from above, the cheeks being quite broad at the top and the frons but little hollowed between the eyes. From in front the outline is nearly circular. Clypeus and frons rather sparsely golden pubescent almost to the ocelli and with quite numerous long yellow hairs. Anterior margin of the clypeus with its middle third straight, transverse, and with a small tooth at each end of this portion where the margin bends upward, just above which is a small, noticeable red spot. Centre of the clypeus somewhat arched; but a rounded triangular area from the highest point of this to the margin is flattened. Frontal suture from the antennae to the anterior ocellus well developed, and this region is without pubescence. Ocellar area well marked by depressed lines. Immediately behind it is an elevated transverse-oval area a little wider than the ocellar area. The portions of the frons, vertex, and occiput not pubescent are black sericeous, which on the cheeks close behind the eyes, and covering the whole of the cheeks lower down, becomes golden sericeous. Cheeks wide above, narrowing quickly below the level of the neck, and giving a long wedge-shaped piece, when viewed from the side, the surface above bearing a few scattered, long yellow hairs. Lateral ocelli nearer each other than to the eyes. Inner margins of the eyes parallel. Antennae black, black sericeous, the scape reddish beneath except at its tip, glistening, and with a very few short black hairs. Relative lengths of filament segments 1/31, 2/19, 3/20, 4/19. Mandibles stout, each reaching but little beyond the base of the other, the terminal tooth and inner margin black as far toward the base as the inner side of a well-developed lateral tooth; the remainder red, with scattered aciculations and a fringe of quite long red hairs on the posterior face.

Thorax black; the dorsal edge of the collar, mesonotum, scutellum, postscutellum, middle of the dorsum of the median segment, front of the tegulae, prothoracic lobes, a large triangular area extending backward from the lower part of the episternal groove of the mesopleuron toward the mesocoxae, a large spot on each side of the petiole on the end of the median segment, and a strip along the side of

the dorsum of the median segment from the last to the postscutellum, golden to yellow sericeous or pubescent. In the specimen at hand the prothoracic lobe, the mesopleural triangular area, and the two spots on the end of the median segment are densely pubescent; the others are coarsely sericeous only; but as this specimen shows traces of having been wet, some of the sericeous areas were probably once pubescent. Anterior face of the collar rising perpendicularly from the neck, slightly rounded from side to side; its dorsal edge rather broad and rounded in both directions; the surface of the collar black sericeous where not yellow. Sides of the collar slightly glistening, with a broad groove running obliquely downward and backward, on the posterior side of which, in front of the prothoracic lobe, are a few striations. Lateral suture of the neck and collar slightly fringed with short yellow hairs. Mesonotum rising considerably above the collar, with a median groove extending back about half the length of the plate. Lateral margins of the mesonotum strongly reflexed to its posterior corners, where this reflexed edge is continued inward by the lateral anterior margin of the scutellum a short distance. It then turns backward, and soon unites with the central part of the scutellum, which is rounded downward anteriorly. Scutellum with a slight median depression posteriorly, on each side of which are a few coarse longitudinal striations. Postscutellum without a median depression, but with coarse striations, as on the scutellum. Dorsum of the median segment with its surface back to the stigmata sericeous or pubescent, which behind this grows narrower till it reaches the posterior end, the sides of the dorsum, which is much broader behind the stigmata, lateral to the sericeous covering, being coarsely striate, the striations being nearly but not quite transverse. Posterior end of the median segment sericeous where not pubescent. Sides of the median segment coarsely rugose, the ridges running nearly vertical posteriorly, and obliquely downward farther forward. Numerous short yellow hairs are present on this surface. Mesopleuron with numerous punctures, coarser below, with yellow hairs. Below the triangular pubescent spot are short, rather irregular ridges running nearly vertical and soon becoming obsolete, below which the surface is sparsely punctured and bears yellow hairs. Metapleuron with striae or rugosities running obliquely forward and downward on the upper part of the plate, vertically downward on the lower part. Near the upper, outer angle of the metacoxa is a pronounced, flattened tubercle.

Abdomen. Petiole of two segments, the first cylindrical, black, somewhat grayish sericeous, the second elongate conical, black near its base above and below, the remainder red, five-sixths as long as the first segment. Remainder of the abdomen entirely red except a band of blackish on the fourth dorsal plate which covers all but the posterior margin and a very small place on the median line anteriorly, and is lighter along the median line. Posterior margin of the seventh dorsal plate oval in outline. Surface of the abdomen grayish sericeous above, somewhat glistening beneath, and here with scattered punctures most abundant on the posterior part of each plate, and more abundant on the seventh. Posterior margins of the third to sixth ventral plates inclusive, rounded, with a central emargination which becomes more of a notch behind. Seventh ventral plate conical, its sides rolled in at the tip so that with the end of the dorsal plate a nearly circular opening is formed; its surface bearing numerous whitish hairs, chiefly at the sides near the end.

Wings, hyaline, the fore wings with a yellowish tinge from the base to the

outer end of the inner cells. Outer margins of both pairs faintly fuliginous beyond the cells. Cubital vein of the fore wing entirely obsolete beyond the third cubital cell except for a very short stub. Subdiscoidal vein also with a short stub beyond the second recurrent, but with a dark streak extending a short distance beyond. Radial vein of the hind wing with a short stub and darker streak beyond the transverse cubital. Cubital not extending beyond the transverse cubital. Veins brown, the subcostal and anal of the fore wing, and the anal of the hind wing, almost black. Tegulae dark brown, lighter behind, golden sericeous, almost pubescent except near the hinder margin.

Legs. Coxae and trochanters black. Fore coxae and trochanters slightly yellow sericeous, the former with scattered yellow hairs. The other segment of the fore legs red, more or less sericeous, the last two tarsal segments darker than the others. Claws dark brown. Middle and hind legs like the fore legs except for a slight dark streak on the posterior side of the hind femora. Spines on all the legs red. Fore metatarsus with eight comb teeth on the outer margin.

Length, 31 mm. Expanse of wings, 40 mm.

Described from one female specimen taken at Cordova, Argentine.

This striking species closely resembles *eugenia* Smith, but differs from it in the outline of the clypeus, the sculpturing of the dorsum of the median segment, and in the distribution of color on the abdomen and legs. If this insect is subject to much variation, it may prove to be Smith's species.

Sphex fragilis (Smith).

Twenty-three female, sixteen male specimens. Length: females, 15–23 mm.; males, 13–20 mm.

"Common on the altos about the last of October on the yellow flowers of a Cladrastis (Chanar)." Davis.

This interesting series shows much variation in size and in the amount of red present on the abdomen, but every gradation between the extremes is present, and I am unable to make more than one species of the lot. Most of the specimens come nearer *suavis* Burm. than to *fragilis*, but as the difference between the two as given by Burmeister consists only in a larger amount of red in *suavis*, it would seem to be simply a color variation.

In all the specimens, at least the median dorsal surface of the last three abdominal segments is black. In many the black areas are broader, covering more of the surface of these plates; in others the black begins to affect the posterior ventral plates and extends farther forward above, and this extension of the black proceeds till in some specimens only the second segment of the petiole, the segment next behind this, and the anterior margin of the next, are red, and the base of the second petiole segment is black or dark above. As the black increases in amount it becomes more bluish in quality, as is called for by the description of *fragilis*. None of the specimens show any tendency toward the appearance of *moneta* Smith, as mentioned by Fox (Proc. Acad. Nat. Sci. Phila., 1897, p. 374).

Considerable study of the South American species of this genus leads to the belief that variation in the amount and distribution of color has resulted in the description of a number of species which will not prove valid when large numbers of specimens can be brought together for study, but a careful examination of the types in various European museums should precede any work of this kind if trustworthy results are to be expected.

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THE PALOLO WORM, EUNICE VIRIDIS (Gray).

By W. McM. Woodworth.

With Three Plates.

CAMBRIDGE, MASS., U. S. A.:

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May, 1907.

No. 1. — *The Palolo Worm, Eunice viridis (Gray).*

By W. McM. Woodworth.

The Palolo worm[1] first became known from the Samoan Islands, where it attracted the attention of the missionaries because it was eaten, prized and sought for by the natives, and because it appeared periodically in certain localities in enormous numbers, and for a few hours only, and because it made its appearance almost invariably in the months of October and November, and always during a quartering of the moon, and was not seen again until the following year under precisely the same conditions. It further became known that the November crop was vastly larger than that of October, and that *all* "Palolo" were *headless.*

The earliest published description of the "Palolo" is that by J. E. Gray (**1847**), based on material sent to the British Museum by the Rev. J. B. Stair, a missionary in the Samoan Islands. Gray placed it near to the Arenicolidae and gave it the name *Palola viridis.* It was figured by Macdonald (**1858**), and although his figures are most accurate, the so-called head is that of a Lysidice, as was pointed out by Ehlers (**1868**), who renamed it *Lysidice viridis.* The first extended account was written by Collin (**1897**) as an appendix to Krämer's earlier work on Samoa. Collin, with previous writers, considered the "Palolo" to be the posterior part of a Lysidice, a few heads of which had, from time to time, been taken with the "Palolo" at the 'fishing' season, and as no other annelid heads were taken, and all "Palolo" were headless, it was natural, for want of better evidence, to ascribe the "Palolo" to the genus Lysidice.[2] For thirty years it was ascribed to that genus, and Macdonald's

[1] In the Fijian Islands the worm is called "Bololo," pronounced Mbololo by the natives. In the course of the present paper I shall use the Samoan name Palolo, for it was in the Samoan Islands that it was first heard from and its true history became known. When the name is printed "Palolo," *i. e.* in quotation marks, I refer to the headless, epitokal, free-swimming portion of the worm. Different writers have spelled it Pulolo and Palola. It has also been called the "Fiji Worm."

[2] Quartrefages (**1858**) calls it *Lysidice palola.*

figures were the only ones,[1] and were often copied. In 1898 Friedlaender (**1898**[a]) figured the head of what he recognized to be that of a Eunice. This, with other material, he obtained from the reef-rock at Samatau in Samoa. His material was afterwards studied by Ehlers, who (**1898**) showed that Friedlaender had found the real head of the "Palolo," which then became *Eunice viridis* (Gray).

It was my good fortune, while acting as assistant to Mr. Alexander Agassiz in the Fiji Islands, to be present at the annual 'rising' of the "Palolo" (Mbololo) at Levuka on November 17th 1897, and Mr. Agassiz has (**1899**, p. 16) given an account of our experiences at that time. In the following year Mr. Agassiz dispatched me to Samoa to be on hand for the November appearance of the "Palolo" and to search the reef-rock for the entire animal. On my arrival at Apia I was fortunate in finding Dr. Krämer, who placed his notes at my disposal as well as all of the annelid material he had collected from the reefs in his search for the Palolo head. I am also under obligations to Mr. W. Blacklock, U. S. Vice Consul at Apia, to Captain Victor Schoenfelder of H. I. M. S. "Falke," to my friend C. L. Crehore who accompanied me to Samoa, and to Tui Malealiifanu, the head chief of Falelatai where I made my headquarters.

After searching the reefs to the westward, at Samatau, where Friedlaender obtained his material, for several days without result, the natives took me to a small bay called Fagaiofu to the eastward of Falelatai. The bay lies between two small promontories which are about one quarter of a mile apart, and is almost filled with a fringing reef, the sea edge of which is not more than two hundred feet from the beach at extreme low tide. Small patches of dead coral occur almost at the beach line, becoming larger and more numerous seawards, where they are more or less confluent so as to make a kind of platform. This general platform is interrupted by two deep narrow channels or passages corresponding to the outlets of small streams. At extreme low tide, that is at neap tide, the place is so shallow that one can wade from the shore to the outer edge of the reef platform. The reef at Fagaiofu is composed of dead coral and the usual honeycombed reef-rock, except at the outer edge where there is living coral. By prizing off masses of the rock with a crowbar at the edges of the deeper channels, "Palolo" were disclosed in great numbers and could be seen dangling from the freshly exposed surfaces, and wriggling free into the water to be

[1] McIntosh (**1885**) figured some chætae from material obtained by the "Challenger."

carried seaward by the retreating tide. This was about one hour before dead low water, and just before sunset on November third, two days before the "Palolo" was expected. Masses of the rock were taken back to Falelatai and by means of chisels, forceps, and lamplight, one specimen was obtained complete. The next day, the eve of the expected 'rising', we again went to Fagaiofu to camp for the night, and at low water obtained more material, including three complete specimens. Owing to the great length of the worm and its intricate association with the reef-rock the operation demands patience and delicate handling. It is in the galleries and cavities of the reef-rock that the Palolo has its abode. They were found everywhere on the reef and could be exposed by breaking open the surface, but more easily at the edges of the deeper places. Plate **3** shows, in natural size, a piece of the reef-rock presenting a top view and an end view showing the fractured surface. Fagaiofu is not easy of access, and a boat can land only when there is enough water over the reef. The platform can be worked only at extreme low tides which, in the Palolo season, are the neap tides, and occur about sundown and sunrise. This season is also the rainy season. Stair was present at the "Palolo" 'rising' at Fagaiofu in 1847 and (**1897**), speaks of it as "one of the famous fishing places." It is strange that I should have been the first to visit the place since his time, and almost by accident, and by only a narrow margin of time. The place is an ideal one for the study of the Palolo, if one could be there during some weeks covering the time of its swarming.

I must speak, as briefly as possible, of the petty discussion which appeared between 1898 and 1903 as to whom belongs the credit of first discovering the real head of the "Palolo." In March, 1898, Friedlaender (**1898**) states that the meaning of the Palolo phenomenon was simultaneously discovered by Krämer, Thilenius, and himself.[1] In May of the same year, Friedlaender (**1898**[a]) says that the nature of the Palolo was discovered simultaneously by Thilenius and himself, and later (**1904**), it reads that he alone, and possibly Thilenius, made the discovery. In this paper he quotes me as saying (**1903**) that it was through Krämer's investigations that the true history of the Palolo became known. I refer Dr. Friedlaender to the English edition of my preliminary paper (**1903**[a]) which was translated for Krämer's "Die Samoa Inseln," though not published until a few months later, to see that I was not unfair to him, as he charges. The discovery of the origin of the

[1] In his subsequent publications he makes no mention of this paper, but speaks (**1904**) of his second paper (**1898**[a]) as "meine erste Abhandlung."

"Palolo" was made independently by Krämer and Friedlaender, although the latter was the first to publish an account of his investigations. Friedlaender succeeded in obtaining from the reef-rock at Samatau several specimens of "Palolo," together with the head ends of an annelid of different appearance and much larger size belonging to the genus Eunice. Friedlaender was the pioneer, for he was the first to identify the large head-end as that of a Eunice, and was the first to figure it as well as the transition piece between it and the "Palolo," and it was from his material that Ehlers gave us the final name *Eunice viridis* (Gray). All that I can hope to do is to establish, beyond doubt, the origin of the "Palolo," and confirm the researches of Friedlaender and Krämer, and add something to our knowledge of the morphology, habits, and relationships of this once mysterious worm.

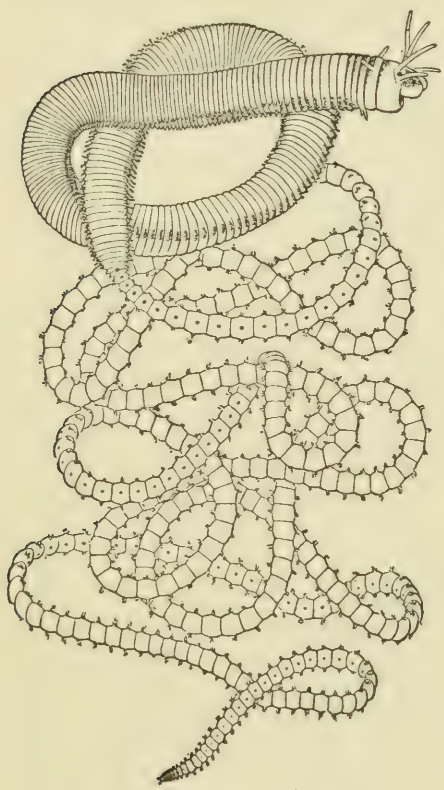

FIGURE 1.

Eunice viridis (Gray). The narrower posterior, epitokal part, when detached and free-swimming, is known as the "Palolo." About natural size.

It was Ehlers (**1898**) who first gave a detailed description of the Palolo worm and recognized an extreme case of sexual dimorphism, and showed the "Palolo" to be the epitokal posterior portion of *Eunice viridis* (Gray). He says (**1898**), "Ich ergänze das im Voraus damit, dass ich die Eunice, die nun den Namen *Eunice viridis* (Gray) erhält, in den Kreis der *Eunice siciliensis* Gr. bringe und an ihr die Ausbildung des "Palolo" als eine Form der Epitokie auffasse, wie sie zum ersten Male aus der Familie der Euniciden, und in ihrer Besonderheit abweichend von allen Erscheinungen der Epitokie, die von Borstenwürmern bekannt sind, sich darstellt. Demnach ist in der Art eine atoke und epitoke Form, in der letzteren eine atoke und epitoke Körperstrecke zu unterscheiden." We have then in the Palolo, combined in the same individual, an atokal and an epitokal part corresponding to the anterior and posterior ends of the animal (Text Fig. 1), and it is the posterior epitokal

part, the "Palolo," that is periodically cast off and leads such an ephemeral existence, while the anterior atokal part remains in the galleries of the reef-rock to regenerate, by a process of strobilization, a new posterior atokal sperm or egg sac, which at the appointed time is again set free. The sexes are different in color, the color of the male being reddish brown or buff to yellowish, while that of the female is a deep bluish green (Figs. 1 and 2). These colors are very pronounced in the epitokal region, and are due to the sexual elements, ova and sperm. After the discharge of the sexual elements the collapsed integument is colorless and translucent. These distinctive sexual colors are found in the broader anterior atokal region, but not in so marked a degree, the female being only a little more greenish in color than the male, and here the colors are doubtless integumentary (Fig. 3). It is from the deep green color of the ova in the epitokal region that the specific name *viridis* is derived. Ehlers (**1898**) has so minutely and accurately described the worm that it would be superflous for me to quote at length the details written by the master's hand, and I refer the reader to his paper. I can only supplement his description by additional measurements, etc., from more abundant material, and supply some figures.

The length of the "Palolo," that is the free-swimming epitokal part of the worm, has been variously estimated at from a few inches to three feet, *i. e.*, a maximum of 90 cm. This great length is given by Gill (**1854**). The longest specimen that I measured in the living condition was 30 cm. This is about the average of the measurements given by seven authors. From alcoholic material, where there is considerable shrinkage, Ehlers estimated 20 cm, and states that some segments were probably missing. The atokal region comprises about one fourth of the total length of the worm, and the greatest diameter is about 4 mm, while the length of the segments is about $\frac{1}{2}$ mm, or about twenty times as broad as they are long. This ratio begins at about the fifteenth segment from the anterior end, not counting the two large cephalic segments (Fig. 3). The ratio of length to breadth of these fifteen segments is about five to one. In the first of the two large cephalic segments the ratio is about two to one, and in the second four to one (Figs. 3 and 7). The broader anterior segments are also marked by a brown pigment which is densest on the dorsal surface, diminishing toward the sides and disappearing toward the ventral surface. It is densest in the two large cephalic segments diminishing posteriorly, and ceases at about the fifteenth segment, where they become shortest (Fig. 3). In one male specimen 429 atokal segments were counted, in another 350. These

counts are not accurate owing to a dense gelatinous secretion in the posterior part, which makes it difficult to count the very short segments. The region of this secretion, in the longest of the atokal specimens, began at about segment 300 and extended backward to the narrow epitokal region. The transition between the broad atokal and attenuated epitokal regions is abrupt and very marked (Text Fig. 1 and Fig. 10, Plate 2), owing to the difference in diameter and shape of the segments and the difference in color due to the sexual elements in the epitokal segments. The diameter of the epitokal segments is, in general, slightly more than 1.50 mm in alcoholic material, and the length is about the same. In the living animal the length of the segments is slightly more than the breadth. The epitokal region has somewhat the appearance of a string of beads, the segments being rounded, bulging at the middle and constricted at the dissepimental zones (Text Fig. 1). [1] As has already been mentioned, the epitokal region is but an egg or sperm sac and leads but a brief free existence, and as will be seen later, the rounded, plump shape of the segments can be explained by the suppression of organs due to the crowding effect of the sexual products. Beginning at about the fifteenth from the posterior end, the segments become narrower and more flattened so that the posterior end tapers to the last or anal segment. Varying from two to fifteen in number, the preanal segments are colorless and translucent, not containing any sexual elements (Fig. 9). The cephalic and anal cirri (Figs. 3 and 9), the chætae (Figs. 13 and 14) and the jaw apparatus (Figs. 11 and 12), are characteristic of the genus, and have been minutely described by Ehlers. The great length of the cirri on the first pair of parapodia described by him is plainly seen in Figure 3. Ehlers finds many resemblances between *Eunice viridis* and *E. siciliensis* Gr. in which species there is also, at sexual maturity, an intensification of the color in the posterior region. With Ehlers, I found the gill filaments in the atokal region to begin at about the 135th segment. They attain their greatest length at about segment 175. The presence of gill filaments in the epitokal part is difficult to determine. When they are present they are much aborted, and there is no particular region where they can always be found. They are constantly absent in the empty, translucent, preanal segments. Ehlers believes that where the gill filaments are lacking in the epitokal region they have been lost, "abgefallen," due to their slight union with the dorsal cirrus, and that the loss of them may be due to one of the regular processes involved in the life of the "Palolo." This is in accord with other processes that take place, such as the general histol-

ysis of internal organs to make room, as it were, for the accumulation of sexual products, and the reduction in the number of chætae in the parapodia, processes adapted to its function and brief existence; while the life of the atokal, parent-end is, as far as known, perennial. The general shape of the parapodia in the atokal and epitokal regions is the same; those of the anterior region being perhaps somewhat broader, and containing a larger bundle of chætae, both simple and compound. In the epitokal region I found usually, even as far back as the thirteenth preanal segment, two of the simple, dorsal chætae and three of the ventral compound ones (Fig. 13), while Ehlers says, "ist häufig nur eine einfache und eine zusammengesetzte Borste vorhanden." A reduction of organs and histolysis of tissues in epitokal forms of annedids has been noted by Ehlers (1868) in Glycera, Caullery and Mesnil (1898) in Dodecaria, by Claparède (1870) in Polyopthalmus and Pædophylax, Eisig (1887) in Notomastus, etc., and McIntosh (1885) has spoken of it in the "Palolo." The intestine is reduced to a thin flattened ribbon, and the segmental organs are difficult to determine, more especially so in the female. Also there is a great reduction in the thickness of the body wall, a condition that exists in other annelids at sexual maturity.

All sexual products, according to Powell (1883), are discharged through "oviducts and seminal ducts," and Ehlers believes, with Powell, that the sexual products are discharged by means of "ausführende Apparate." My observations do not agree with this. In Fiji I isolated single individuals in separate vessels and observed the discharge of the sexual products, which was best seen in females on account of the large size and deep color of the ova. In one instance, a female of about ten inches in length, the ova were discharged as if simultaneously from all segments, leaving a small mass of shriveled translucent pellicle. It seemed incredible that so large a worm could be suddenly reduced to so small a mass. The process was like an explosion, and the ova must have been under great tension. When a few specimens were kept in the same vessel, the number of heaps of green granules at the bottom of the vessel indicated the number of females that had discharged their ova. On examination of the collapsed integument, distinct lateral rents or tears could be seen, and could, in some cases, be traced confluent through several segments. The large size of the ova, 14.5 μ in diameter, would preclude any rapid discharge by means of segmental organs. On the other hand I believe that some of the male elements may find their way out through the segmental organs as they can be demonstrated there in sections; yet living males "explode" in the same

way as females. Eisig (1887) describes similar conditions in Notomastus, where the sexual elements are discharged by rupture of the body-wall, and states that the lumen of the segmental organs is too small for the passage of ova. Mayer (1900), for his "Atlantic Palolo," says that by series of violent and sudden contractions "the ripe segments are torn asunder at short intervals by the breaking of the cuticula, forming large rents through which the genital products escape." This manner of unloading the sexual products accounts for the apparent sudden disappearance of the dense swarms of "Palolo" a short time after their appearance, which was considered as much of a phenomenon as their sudden appearance.

Each segment of the atokal part bears on its ventral surface a prominent circular pigmented spot, deep brown or black in color (Text Fig. 1, Figs. 9 and 10, plate 2). They can be traced forward into the atokal region through about twenty segments, though much reduced in size, and paler in color (Fig. 10). They are absent in from two to fifteen of the preanal segments, those colorless, translucent segments that contain no sexual elements. They were first noted by Ehlers (1868) who likened them to eyes in appearance, but looked upon them as the external openings of some sort of a longitudinal gland. It was Spengel (1881) who first estimated their true nature, and speaks of them as "wirkliche Augen." The minute structure of these ventral eye-spots was studied by Hesse (1899) in carefully prepared material collected by Krämer. Although he states that it is improbable that they are capable of forming images, he says: "Es wird also ihre Leistungsfähigkeit auf die Unterscheidung verschiedener Lichtsintensitäten, vielleicht auch von Farben, und auf das Erkennen der Lichtsrichtung beschränkt sein." Schroeder (1905), who also made an histological study of these eye-spots, asserts that they differ so much in structure from all known eyes that it is not possible to compare them with any. He hints at the possibility of their being light-producing organs. If they were phosphorescent organs it would have been noted long ago, and could not have escaped the eyes of the natives, as the "Palolo" appears in dense swarms at the surface of the water, and in deep darkness. It is significant that these eye-spots occur in a rudimentary form on only a few of the posterior segments of the atokal, sedentary, part of the worm, and are so highly developed on all but a few of the segments of the active, epitokal part. I believe with Hesse that they react in some way to light, or possibly to heat rays. In text Figure 2, I reproduce Hesse's figure of a median section of one of these eyes, which plainly shows their structure.

On the day before the 'rising' of the "Palolo" (the *motusaga* day of the natives, see *infra*), a small annelid, headless like it, and the sexes also distinguished by brown and greenish tints, makes its appearance in large numbers. It is this small worm that in my preliminary paper (1903) I ascribed to *Lysidice falax*, the name that Ehlers gave to the Lysidice-head figured by Macdonald, and for so long believed to be the

FIGURE 2.

Longitudinal medium section of one of the ventral eye-spots of the "Palolo." After Hesse. × 400. *v. n. c.*, ventral nerve-cord ; *p. m.*, pigment mass ; *ep.*, epithelium.

real head of the "Palolo." This small headless worm, a diminutive "Palolo," does not belong to *L. falax*. I have complete specimens of the latter which in no way exhibit any heteramorphosis or differentiation between the anterior and posterior regions. A description of *L. falax* is reserved for a subsequent paper on Eunicidae from the reefs of the Pacific Islands. To the little "Palolo" of *motusaga* day I give the tentative name *Eunice dubia*. The segments have the same general shape as those of the "Palolo" and measure, in alcoholic material, about 0.75 mm; in diameter, being slightly shorter than broad (Figs. 4 and 5). As

in *E. viridis* about twelve of the preanal segments are colorless and translucent, not containing any sexual elements. These empty segments are usually much wider than those preceding them, thus marking off a distinct broader preanal region (Fig. 5). The longest specimen measured 3 cm, from the material collected by Krämer at Apia. Usually there is present, in each segment, a pair of brownish or blackish pigmented spots at the dorsal base of the parapodia (Fig. 6). These are not comparable to the ventral eye-spots of *E. viridis*, but rather to the paired pigmented "glands" so common in the Alciopina and Tomopteridae and, possibly, have a photogenic function. Treadwell (**1900**) has described similar paired organs in *E. armata*. The composition of the parapodia (Fig. 15) is much simpler than in *E. viridis*. There are two of the simple chætae, one much longer than the other, and but one of the compound kind. The figure does not show the cirri which are much shorter than in *E. viridis*, and gill filaments could not be determined; the figure is inverted.

The first detailed account of sexual dimorphism in annelids is by Alexander Agassiz (**1862**) for Autolytus, and Malaquin (**1893**), has called attention to its occurrence in other Syllidae. In the Nereidae, sexual dimorphism was first described by Ehlers (**1868**) where it is known for upwards of twenty species, and it is manifested in different ways pretty much throughout the Annelida. It occurs in two general ways. First, as in the Nereidae, where certain sexual individuals undergo a metamorphosis adapting them for the dissemination of the sexual products (Heteronereis), and secondly as in the Eunicidae ("Palolo"), where certain regions of the animal, containing the sexual elements, become modified and are set free by a process of autotomy. In the first case the metamorphosed individuals are known as the epitokal (Ehlers, **1868**) or epigamous (Claparède, **1870**) forms, in the latter the sexually modified part which is set free is the epitokal part of the animal, the unmodified part, the parent animal, which may or may not regenerate the liberated portion, is the atokal part. In the latter class it is usually the posterior portion that is set free as in *Eunice viridis*, *E. fucata* (Mayer, **1900**, **1902**) Syllidae, etc., while in *Ceratocephale osawai* (Izuka, **1903**), one of the Nereidae, it is the anterior region that leads a free existence. In most epitokal forms there is a great development of the eyes. In the Nereidae, the active epitokal form is attracted by artificial light, and Izuka (**1903**), states for Ceratocephale that the fishermen attract them by the light of torches, catching them for bait. I have observed the same attraction to artificial light in several forms of Heteronereis. This development of the eyes in epitokal phases of annelids is significant, and as I have pointed

out the ventral eye-spots are fully developed only in the posterior free-swimming part of the Palolo.

According to Riggenbach (**1902**) autotomy (Selbstverstümmlung) in annelids is brought about through external stimuli, and the parent atokal part of the Palolo may be looked upon as a sexual nurse or stock which regenerates the epitokal region, a process comparable to strobilization in cestodes. Brunelli and Schoener (**1905**), who name this process schizoepitokie, call attention to the fact that the most complicated reproductive processes in annelids exist in those forms that inhabit shores and reefs, are simpler in pelagic forms, still less complicated in fresh water forms, and simplest of all in terrestial forms. In the phenomenon of the periodic appearance of the "Palolo" they believe that inorganic forces have played the most important part in establishing reproductive autotomy, and since annelids inhabiting reefs and shores are subject to wounds and amputations due to the action of the waves on rock-fragments and sand, and friction between the worm and the rock, etc., epitokie arose from such amputations, which later became simple division and finally adapted to the dissemination of the species, and since these mechanical causes were coincident with certain seasons, such a periodic seasonal mechanical stimulus has played an important role in the ancestral history of the Palolo.

The periodic swarming of the "Palolo" has been ascribed to various stimuli such as light, heat, salinity and pressure of the water, atmospheric electricity, etc. Friedlaender (**1898**), says that a reaction to light has nothing to do with the "Palolo" phenomenon, neither moonlight, which is reflected light, nor the light of dawn, and suggests a negative geotropism through diminished water pressure at low tides. The "Palolo" appears in the months of October and November in the last quartering of the moon. This is the season of neap tides, when the reef flats are uncovered or only awash. At this season the sun is nearest the zenith in southern latitudes, a season when the sun's light and heat is greatest. I believe in some heliotropic or thermotropic reaction of the eye-spots borne on the segments of the epitokal part of the Palolo. A glance at Text Fig. 2, p. 11, showing the structure of one of these ventral eye-spots is more than suggestive that their function is to react in some way to light or heat rays. Friedlaender's contention that the "Palolo" appears in almost absolute darkness does not, to my mind, preclude a reaction of the eye-spots to light or heat, for these influences have been acting for a considerable period of time as there are three distinct days involved in the 'rising' of the "Palolo."

The "Palolo" makes its appearance twice a year and always in a quartering of the moon, at a neap tide in October and November. For Fiji the October rising is known as "Bololo lailai," *i. e.*, small or few "Palolo;" the November one is called "Bololo levu," *i. e.*, large or many "Palolo." The October crop is not large enough to interest the natives in its capture, but marks in a way the time for the appearance of the great November crop.[1] There are various signs known to the natives by which they reckon when to expect the swarming of the worm, such as the distance above the horizon of certain constellations, the "march" to the sea of the land crabs to deposit their eggs, the appearance of certain small fish, the ripening of certain tubers, the flowering of plants, etc. An old Fijian chief told me that you might expect the "Bololo" when in the last quartering of the moon in October and November there is a low tide just before sunrise. This spring season is recognized throughout the Pacific islands, and where the "Palolo" occurs the native calendar bears its mark as to the names of seasons and months. All of the annelids living in the reefs are sexually mature at this time, as shown by the extensive collections made by Krämer and myself, and this is true of the general animal life of the reef. In Samoa this season is known as *taumafamua*, *i. e.*, the time of much to eat. In the Banks Islands, Mota (Codrington, **1891**), the season is called *tau matua*, the season of maturity.[2]

Good accounts of the fishing of the "Palolo" are given by Churchill (**1902**), Churchward (**1887**), Krämer (**1902**), the Earl of Pembroke (**1872**), Seeman (**1862**), Stair (**1897**), Thompson (**1896**), von Werner (**1890**), and others. The 'Palolo-time' embraces three successive days. When in the last quarter of the moon in October and November, more especially the latter, the water on the 'Palolo-grounds' has a turbid or roiled look, with floating patches of scum, the natives know that two days later the "Palolo" will 'rise.' This first day is called *salefu*. The second day is marked by the swarming of a small annelid, headless like the "Palolo," and the sexes distinguished by the same yellow and greenish tints. This day is called *motusaga*. The third is the *tatelega* when the "Palolo" swarms and the natives come many miles to the favoured places to gather it. With "Palolo" of the *tatelega* day many of the small annelids of the *motusaga* occur, and a few "Palolo" appear

[1] I can offer no explanation why there should be two distinct crops and in adjacent months, nor why the November crops should be so much larger.

[2] It is not in the province of this paper to enter into the legends, folk-lore, and ceremonies of the natives with which the "Palolo" has so much to do.

on *motusaga* day. A microscopical examination of the *salefu* scum shows it to consist of a gelatinous slime in which are grains of sand, appendages, fragments and casts of Entomostraca, and a varied detritus of the seething life inhabiting the reefs, including many ova of various kinds in different stages of segmentation. The *salefu* may be looked upon as a manifestation of the awakening of the "Palolo" previous to its swarming or marriage-swim; an annual activity of countless numbers of annelids resulting in a discharge into the water of the deposits accumulated in the galleries and crevices of the reef-flats. The small annelid of *motusaga* day is what I have called *Eunice dubia* (Figs. 4–6, 15) and is doubtless what Friedlaender speaks of as the "Pseudo-palolo." The "Palolo" appears in some localities in such enormous numbers that the surface of the sea has been likened to a thick vermicelli or macaroni soup, and I have seen a native with his bare hands fill a large pail with the worms in a few minutes. In Fiji I have seen the natives testing the water by wetting their hands and smelling it, and in this way detect the presence of the worm before it had been seen. I was unable to learn of this method in Samoa. The "Palolo" is eaten raw, but more usually baked in leaves of the breadfruit or boiled. The mass resembles cooked spinach in appearance, the whole taking on the deep green color of the female. In taste and smell it is not unlike fresh fish roe. It is eaten with impunity by both old and young, and in Fiji the water in which it is boiled is sometimes given to the sick.

The "Palolo" is known from Samoa, Fiji, and Tonga. It occurs on all of the larger of the Samoan Islands and throughout the Fiji group. Early records of the time of its appearance in Fiji have been kept at Lakamba from 1845–1854, and at Levuka from 1854–1858. In every case its appearance was in a quartering of the moon, which is true also of Whitmee's records for Savaii in Samoa (1862–1868) and the later records from both groups of islands.

The earliest recorded observations of the swarming of annelids are those of Rumphius (**1705**) for the "Wawo" of Amboina for the years 1684 to 1694. The recent "Siboga" expedition brought back specimens of this worm which were studied by Horst (**1905**) who named it *Lysidice oele* (see also Weber, **1902**). As in the "Palolo" its annual appearance is directly related to a phase of the moon, as it makes its appearance in March and April only on the second and third nights after full moon. This relation of swarming of annelids to phases of the moon is noted by Mayer (**1900** and **1902**) for *Eunice fucata*, and Izuka

(1903) for *Ceratocephale osawai.* A similar swarming of marine annelids, and at corresponding seasons, is known for other islands of the Pacific, though the worms have not everywhere been identified. Powell (1883) speaks of them in the Gilbert Islands where they are known to the natives as *te nmatamata,* and Codrington (1891) gives a detailed account for Mota in the Banks Islands where they are known as *un.* Brown (1877) mentions an annual appearance of a " Palolo " on the East coast of New Ireland. That the annelid is best known from Samoa and Fiji is accounted for by these two groups of islands having been most visited and longest inhabited by whites. It is significant also that such records as we possess from other places, though meagre, have come to us through the missionaries, the pioneers of intelligent whites in the islands of the Pacific.

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1902. Siboga Expedetie. Monograph I. Introduction et description de l'expedition. Leyden.

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1890. Ein deutsches Kriegschiff in der Südsee. Leipzig.

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1875. On the Habits of Palola viridis. Proc. Zool. Soc., for 1875, p. 496–502.

Woodworth, W. McM.

1903. Vorläufiger Bericht über den Palolowurm nach dem von mir und Dr. A. Krämer auf Samoa im Jahre 1898 gesammelten Material. Die Samoa Inseln. Entwurf einer Monographie mit besonderer Berücksichtigung Deutsch, Samoas. Von Dr. Augustin Krämer. Bd. II, p. 399–403. Stuttgart.

1903[a]. Preliminary Report on the "Palolo" Worm of Samoa, Eunice viridis (Gray). Amer. Naturalist., Vol. 37, p. 875–881.

EXPLANATION OF PLATES.

Figures 1 and 2 were drawn by A. G. Mayer, Figure 3 by M. Westergren, Figures 4 – 10 by J. H. Blake, and Figures 11 – 14 by author.

PLATE 1.

Figs. 1 and 2. The male and female "Palolo," the epitokal parts of *Eunice viridis* (Gray). Sketches to show the colors of the living animal. About natural size.

Fig. 3. Head end of a female. × 3.

Figs. 4 and 5. Female and male epitokal parts of *Eunice dubia*, sp. nov. × about 8.

Fig. 6. Two segments of the epitokal part of *E. dubia*, showing the paired pigmented spots at the base of the parapodia. × 35.

PALOLO

PLATE 2.

FIG. 7. Ventral view of the head end of *E. viridis.* × $4\frac{1}{2}$.

FIG. 8. Anterior view of the head end of *E. viridis.* × 3.

FIG. 9. Anal end of the "Palolo" or epitokal part of *E. viridis*, showing three of the ventral eye-spots and the empty preanal segments, and anal cirri. × 6.

FIG. 10. The transition area between the "Palolo" and the atokal anterior part. Note the small size of the eye-spots on the posterior atokal segments. × 6.

FIG. 11. The jaw apparatus of *E. viridis*, partly dissected. × 12.

FIG. 12. Left half of the jaw apparatus dissected to show the component parts. × 15.

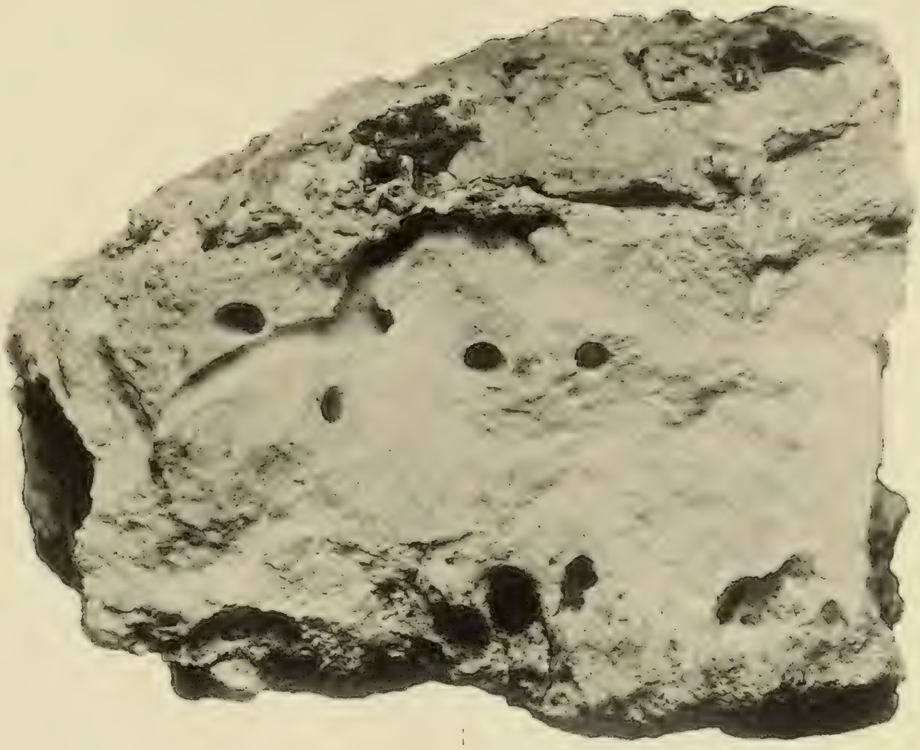
FIG. 13. Parapodium of *E. viridis* from about the fortieth preanal segment. × 92.

FIG. 14. End of one of the compound chætae of same. × 300.

FIG. 15. Parapodium of *E. dubia.* This figure is inverted. × 200.

PLATE 3.

A piece of the reef-rock at Fagaiofu, showing the galleries and crevices occupied by the Palolo. The upper figure shows the fractured surface, the lower one a surface view of the reef-flat. From photographs. Natural size.



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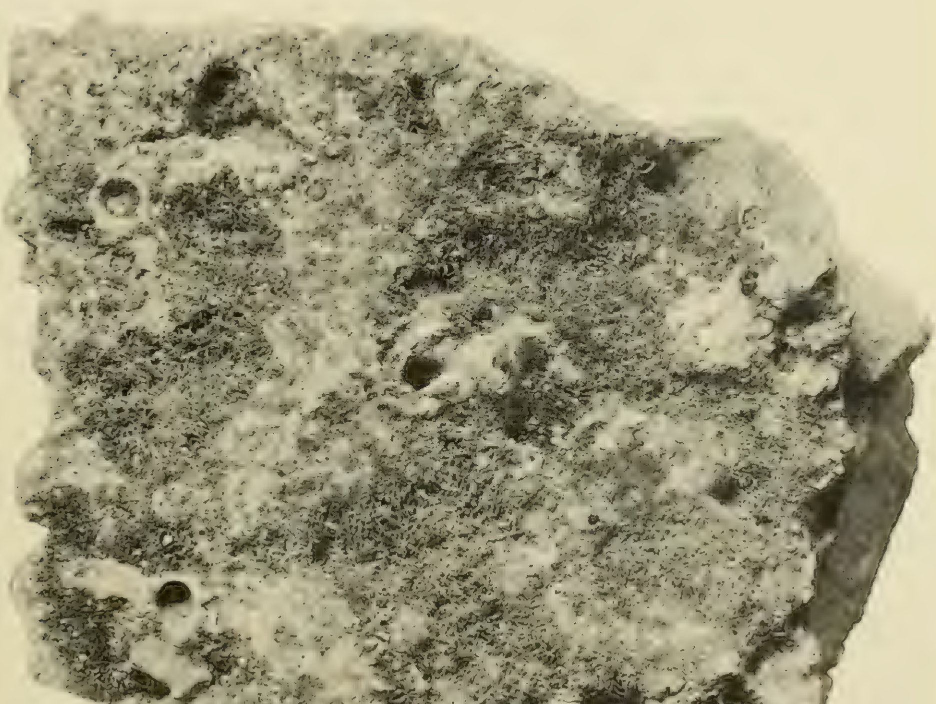


2

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 2.

THE STARFISHES OF THE GENUS HELIASTER.

By Hubert Lyman Clark.

With Eight Plates.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

June, 1907.

No 2. — *The Starfishes of the Genus Heliaster.* By Hubert Lyman Clark.

The starfishes placed by Gray (**1840**) in the group to which he gave the name Heliaster are of more than usual interest because of their limited geographical distribution their exclusively littoral habitat, and the large number of rays which they have. Moreover they appear to be remarkably plastic and there has long been reason to believe that the group contains several well-marked forms, limited to very circumscribed geographical areas. As the collection of the Museum of Comparative Zoölogy contains a large number of specimens from a dozen or more different localities, it seemed worth while to make a careful study of the group, especially with reference to three questions which have been raised concerning it. (1). How many valid species of Heliaster are there, what is their relation to each other, and what is the geographical distribution of each? (2). With how many rays does Heliaster begin its post-larval life, where and how do the new rays arise, in what order, and with how much variability? (3). What is the relation of Heliaster to Asterias and other starfishes, and by what systematic arrangement can that relationship best be shown? In finding the answers to these questions, we discover some important evidence on the subject of isolation as a factor in the formation of new species.

In addition to the material in the Museum collection, I am indebted to Dr. W. K. Fisher, of Leland Stanford Junior University, for the loan of material from the Galapagos Islands, belonging to the Museum of that University, and to Dr. Richard Rathbun, of the United States National Museum, for much valuable material from the collections under his care. To both of these gentlemen I herewith extend my sincerest thanks. In all I have had, from at least 15 distinct localities, 346 specimens of Heliaster, ranging from 20 to 300 mm. in diameter.

Historical.

The following annotated bibliography gives a complete resumé of our knowledge of Heliaster and its several species, from the first published reference in 1767 down to July 1, 1906: —

1767. Davila, P. F.

Catalogue systématique et raissoné des Curiosités de la Nature et de l'Art, qui composent le Cabinet de M. Davila, etc. 3 vols. **1.** Paris.

On p. 462–463 reference is made to three starfishes called "Tournesols," with 13, 37, and 38 rays, and brief descriptions are given of them; it is obvious that the two latter are Heliasters and it is fair to assume that they are *H. helianthus* (Lamarck) as that species was known in Paris, and was figured not many years later.

1791. Bruguière, J. S.

Tableau Encyclopédique et Méthodique, etc. Paris.

The two figures on plates 108 and 109 are fair abactinal and actinal views of a *Heliaster helianthus* (Lam.) with 29 rays.

1816. Lamarck, J. B. P. A. de Monnet de

Histoire Naturelle des Animaux sans Vertebres, etc. 7 vols. **2.** Paris.

On p. 558 Astérie hélianthe, *Asterias helianthus*, is given as the twentieth species of Asterias; it is said to have 30–36 rays (though reference is made to the figure of Bruguière, which has only 29) and to reach a diameter of 14–16 cm.; no locality is given.

1817. Cuvier, G. L. C. F. D.

Le Règne Animal, etc. 4 vols. **4.** Paris.

On p. 11, *Asterias helianthus* Lam. is listed but no information is given.

The numerous other editions and translations of Lamarck's and Cuvier's great works afford us no further information and there are no changes save that in the "Deuxieme Edition" (1840) of Lamarck the starfish is called "Astérie héliante," which is probably a misprint, and reference is made to the names *Solasterias* de Blainville and *Stellonia* Nardo, though neither is adopted; and in the German translation of Cuvier by Voigt (Das Thierreich, 1843) the species *helianthus* is listed under *Asteracanthion*, following Müller and Troschel.

1824. Bory de Saint-Vincent.

Tableau Encyclopédique et Méthodique, etc. Paris.

On p. 140 is the text to accompany the plates of Bruguière (1791), as follows:

Plate 108. Astérie, Asterias. 1–2. Asterias Helianthus, Lam., **2,** 558. (dessus).

Plate 109. Astérie, Asterias. 1–2. Asterias Helianthus, Lam., *loc cit.* (dessous).

1824. Lamouroux, Bory de St. Vincent et Eud. Deslongchamps.

Encyclopédie Méthodique. 10 vols. **2.** Paris.

On p. 119 is a direct quotation from Lamarck (1816) with the added note, "L'on ne connoît point son habitation."

1825. Say, Thomas.

On the species of the Linnean Genus *Asterias,* inhabiting the coast of the United States. Journ. Acad. Nat. Sci., **5**, p. 141–145. Philadelphia.

In a footnote on p. 145 is given the first published information in regard to the home of Heliaster.

" *A. Helianthus* Lam. As the native coast of this splendid species was unknown to Lamarck, I may . . . state that a fine specimen . . . was found near Guasco, . . . Chili."

1830. Blainville, H. M. D. de.

Zoöphytes: in Dictionnaire des Sciences Naturelles, etc. 60 vols. **60.** Strasburg et Paris.

On p. 222–223 *Solastéries* is proposed as a section of *Asterias*, admittedly artificial, for species with more than six rays, and *A. Helianthus* Lam. is named as one of them.

1834. Blainville, H. M. D. de.

Manuel d' Actinologie, etc. Paris.

On p. 241–242 is a repetition of the preceding suggestion, and a very poor figure of half the abactinal surface of *Helianthus* is given, plate 23, fig. 5.

1834. Meyen, F. J. F.

Reise um die Erde, etc. Theil **1.** Berlin.

On p. 222 *Asterias Helianthus* Lam. is said to be "besonders haüfig" on the coast at Valparaiso, and is considered the "ausgezeichnetesten" species of the genus.

1835. Agassiz, L.

Prodrome d'une Monographie des Radiaires ou Echinodermes. Mem. Soc. Sci. Nat., **1**, p. 168–199. Neuchâtel.

On p. 192, there is listed

"— *St. Helianthus* Ag. (Asterias Helianthus Lam.) —",

the *St.* being an abbreviation for *Stellonia* Nardo.

1840. Müller, J. und Troschel, F. H.

Ueber die Gattungen der Asterien, Arch. f. Naturg., Jahrgang 6, **1**, p. 318–326. Berlin.

On p. 321 *A. Helianthus* Lam. is listed as one of eight species of Asteracanthion, and on p. 324 the madreporite of the same starfish is said to be compound, a group of single plates.

1840. Gray, John Edward.

A Synopsis of the Genera and Species of the Class Hypostoma (Asterias, *Linnaeus*). Ann. Mag. Nat. Hist., **6**, p. 175–184. London.

On p. 179 is "Section e" of *Asterias, Heliaster,* defined thus: *Body discoidal, divided at the edge into numerous, short, tapering rays; the series of spines near the ambulacral series rather crowded, large and elongated.*

Asterias helianthus Lam. is given first, obviously as the type species, and is described as having 33 or 34 "arms," which are "about a quarter of the length of the width of the body." It is recorded from Guasco and Valparaiso, Chili. Then follow *Asterias Cumingii* with "arms 30 or 31, very short, not one-tenth as long as the diameter of the body," from "Hood's Island, on rocks at spring tide, *H. Cuming Esq.*," and *Asterias multiradiata* with "arms 22 or 24, cylindrical, elongated, tapering at the ends, one-third longer than the diameter of the body," from "Hood's Island, *H. Cuming Esq.*"

1840. Gervais, P.
Astérie, Asterias (*Actinoz*): in Dictionnaire Sciences Naturelles. Supplément. Paris.

On p. 469 *A. helianthus* Lamarck is assigned to *Stellonia* Nardo; reference is made to Gray's proposed section e (HELIASTER) of the genus *Asterias,* but curiously enough no mention is made of his proposed new species.

1842. Müller, Johannes und Troschel, Franz Hermann.
System der Asteriden. Braunschweig.

On p. 18–19 is given *Asteracanthion helianthus* nob., including *Asterias helianthus* Lamarck, *Asterias Cumingii* Gray and *Asterias multiradiata* Gray. The two latter are dismissed with the brief statement that they "do not appear to us to be different." The compound nature of the madreporite is referred to, the size is said to be "up to one foot" and the native coast is given as "Chili, Pacific Ocean."

1843. Müller, Johannes.
Über den Bau des Pentacrinus caput Medusae. Berlin.

Abschnitt 8. Ueber die Unterschiede des Baues der Crinoideen und Asteriden, p. 61–68.

On p. 64 *Asteracanthion Helianthus* Lam. is listed and on p. 67, the compound nature of the madreporite is mentioned.

1843. Müller, J. und Troschel, F. H.
Neue Beiträge zur Kenntniss der Asteriden. Arch. f. Naturg. Jahrgang 9, **1**, p. 113–131. Berlin.

On p. 128 *Asteracanthion helianthus* is listed among starfishes from the west coast of South America.

1854. Gay, Claudio.
Historia fisica y politica de Chili, etc. 26 vols. Zoölogia. **8.** Paris. Santiago.

On p. 425 is a good account of the "Estrella del Mar," *Asteracanthion helianthus.* It is said to have 28–39 rays and to occur at Valparaiso and elsewhere on the coast of Chili.

1856. **Hoeven, J. Van der, translated by William Clark.**
Handbook of Zoölogy. 2 vols. **1**. Cambridge (England).

On p. 148–149 *Asterias helianthus* with "rays up to 30 and more" is said to be "one of the most remarkable and most beautiful species."

1857. **Carpenter, Philip P.**
Report on the present state of our knowledge with regard to the Mollusca of the west coast of North America. Rept. British Ass. for 1856, p. 159–368. London.

On p. 360 it is stated that *Stylifer astericola* is known from the Galapagos parasitic in *Asterias solaris.* The starfish referred to is unquestionably a Heliaster and probably *H. cumingii* Gray, as many specimens of that species from the Galapagos are parasitized by Stylifer; the name *solaris* would be more naturally applied to this species than to *multiradiatus,* the other Galapagos Heliaster, because of its more numerous rays.

1857. **Philippi, A.**
Vier Neue Echinodermen des Chilenischen Meeres. Arch f. Naturg., Jahrgang 23, **1**, p. 130-134. Berlin.

On p. 134 *Asteracanthion helianthus* is listed among the starfishes of Chili.

1857. **Stimpson, Wm.**
On the Crustacea and Echinodermata of the Pacific Shores of North America. Boston Journ. Nat. Hist., **6**, p. 444–532, plates 18–23. Boston.

On p. 529 *Asterias helianthus* Lam. is given as occurring at "Mazatlan (Moores)." Probably *H. microbrachius* is the species intended.

1860. **Lütken, Chr.**
Bidrag til Kundskab om de ved Kysterne of Mellemog Syd-America levende Arter of Söstjerner. Videns. Meddel. for 1859, p. 25–96. Kjöbenhavn.

There are several references in this paper (p. 27, 31, 32, 35) to the occurrence of Heliasters on the western coast of America, but the writer considers the species in each case to be *helianthus* In a footnote on p. 32, he indicates his doubt as to the location of Hood's Island, his disbelief in Gray's proposed species, and his final opinion that even if valid they do not enter into the West American fauna.

1860. **Bronn, H. G.**
Die Klassen und Ordnungen des Thier-reichs, etc. Die Klassen und Ordnungen der Strahlenthiere (Actinozoa). Leipzig und Heidelberg.

On p. 253 reference is made to the compound madreporite of *Asteracanthion helianthus.*

1860. **Xantus, John.**
Descriptions of Three New Species of Starfishes from Cape St. Lucas. Proc. Acad. Nat. Sci., 1860, p. 568. Philadelphia.

On p. 568 are the original descriptions of *Heliaster microbrachia* and *H. kubiniji.* The former is said to have 35 rays, the free portion equalling one-eighth of the diameter and the dorsal spines very small and numerous. The latter has 22–24 rays, the free portion rather less than one-third of the diameter, and the dorsal spines capitate; the name is said to be in honor of "my countryman, M. Kubiniji, the accomplished director of the Hungarian National Museum at Pesth." Each species is said to be 7 inches in diameter. The specimen of *microbrachia* was from Cape St. Lucas, while that of *kubiniji* was from "Cerro Blanco, Cape St. Lucas."

1862. Dujardin, F. et Hupé, H.

Histoire Naturelle des Zoophytes Échinodermes, etc. Paris.

On p. 329, 343 and 344 *Heliaster* Gray is recognized as a genus, and with *Asteracanthion* forms the first of the three tribes of Asterides. The species *Cumingii* Gray and *multiradiatus* Gray are however considered doubtful, and although the characters given by Gray are mentioned, the species are included in the synonymy of the single accepted species, *Heliaster Helianthus* Lam. (Sp.). The color of this species is said to be "variée de blanc et de noir, comme tigrinée"; the size, 20–30 cm.; the distribution, "Coast of Chili" (thus ignoring Gray's records from the Galapagos). The gastropod *Stylifer* is recorded as a parasite. No mention is made of Xantus's paper (1860) or of his proposed species.

1866. Martens, E. von.

Ueber Ostasiatische Echinodermen. Arch f. Naturg., Jahrgang 32, **1**, p. 57–88. Berlin.

On p. 60 *Heliaster* is used as a subgenus of *Echinaster* to include *solaris* Schmidel, and "Hupé und Dujardin" are quoted for authority. In this extraordinary slip of the pen are three distinct errors. (1) Hupé and Dujardin never published anything with the former as senior author. (2) Dujardin and Hupé (1862) use Heliaster as a separate genus and neither they nor any other author ever used it as a subgenus of, or allied to Echinaster. (3) Schmidel never gave the name *solaris* to any species of starfish, though in 1781 he described one, to which Schreber, twelve years later, gave that name! The starfish to which von Martens refers is obviously *Acanthaster echinites* (Ellis and Solander). — On p. 68 von Martens speaks of the peculiar madreporite of *Asterias helianthus.*

1866. Gray, John Edward

Synopsis of the Species of Starfish in the British Museum. London.

On p. 2 is what is practically a reprint of that part of p. 179, Gray 1840, which deals with Heliaster, except that *Heliaster* is now section f, instead of section e, of the genus *Asterias.*

1867[a]. Verrill, A. E.

Notes on the Echinoderms of Panama and West Coast of America, with descriptions of new Genera and Species. Trans. Conn. Acad., **1**, p. 251–322. New Haven.

On p. 289-293 are good descriptions of *Heliaster helianthus, microbrachia, Cumingii* and *Kubiniji,* with special attention given the pedicellariae. The description of *Kubiniji,* which is considered distinct from *multiradiata* Gray, is based on a specimen "obtained at the Sandwich Islands. It probably came from Acapulco or Mazatlan." This specimen is of interest chiefly because, through a mistake of Perrier's, it is the source of all Hawaiian records.

1867 b. Verrill, A. E.

On the Geographical Distribution of the Echinoderms of the West Coast of America. Trans. Conn. Acad., **1**, p. 323–351. New Haven.

The geographical distribution of the genus *Heliaster* and of *H. Cumingii, helianthus, Kubiniji, microbrachia,* and *multiradiata,* is referred to on p. 328, 329, 331, 333-335, 344, and 348.

1868. Claus, Carl

Grundzüge der Zoologie, etc. Marburg und Leipzig.

On p. 107 *Asteracanthion helianthus* is referred to as having "30 und mehr" rays.

1869. Perrier, Edmond.

Recherches sur les Pédicellaires et les Ambulacres des Asteries et des Oursins. Ann. Sci. Nat., (5) **12**, p. 197–304, plates 17–18. Paris.

On p. 202–203 Heliaster is recognized as a good genus, but on p. 231 the writer decides it is not valid. A description of the pedicellariae of Asteracanthion and Heliaster occupies p. 202–219 and on plate 7 is a figure (16) of a forcipiform pedicellaria of *Asteracanthion helianthus.* On p. 203 it is stated: "Dans toutes les espèces appartenant aux genres *Asteracanthion* et *Heliaster* on trouve deux sortes de Pédicellaires, nous designerons . . . l'une . . . *Pédicellaires droits,* l'autre . . . *Pédicellaires croisés.*" But on p. 231 under *Heliaster helianthus,* the writer says, "Nous ne connaissons pas encore les pédicellaires droits"!

1869. Verrill, A. E.

On New and Imperfectly Known Echinoderms and Corals. Proc. Boston Soc. Nat. Hist., **12**, p. 381–396. Boston.

On p. 387 are some notes on a large specimen of *Heliaster Kubiniji* from La Paz having 23 rays.

1871 a. Verrill, A. E.

Additional Observations on Echinoderms, chiefly from the Pacific Coast of America. Trans. Conn. Acad., **1**, p. 568–593. New Haven.

On p. 578 are some further notes on *Heliaster Kubiniji* Xantus.

1871 b. Verrill, A. E.

The Echinoderm Fauna of the Gulf of California and Cape St. Lucas. Trans. Conn. Acad., **1**, p. 593–596. New Haven.

This brief paper contains several references to the geographical distribution of Heliasters on the coast of Mexico.

1871. Cunningham, Robert O.

Notes on the Natural History of the Strait of Magellan and West Coast of Patagonia, etc. Edinburgh.

On p. 404 a 38-rayed specimen of *Heliaster helianthus* is referred to as a "huge" starfish taken at Pelican Rock, near Coquimbo, Chili. Unfortunately no measurements are given.

1871. Lütken, Chr.

Fortsatte kritiske og beskrivende Bidrag til Kundskab om Söstjernerne (Asteriderne). Viddens. Meddel. for 1871, p. 227–304, plates 4–5. Kjöbenhavn.

On p. 289 is an unimportant reference to "*Asterias microbrachia* Xantus," and on p. 304 the occurrence of that species and "*Heliaster Kubinjii*" at Altata, Mexico, is noted.

1872. Lütken, Chr.

Om Selvdeling hos Echinodermer og andre Straaldyr. Overs. K. Danske Vid. Sels. Forh. for 1872, p. 108–157. Kjöbenhavn.

On p. 121 is a trivial reference to Heliaster and in a footnote (2) on p. 125 et seq. is an interesting discussion of the correlation between size and number of rays in "*Asterias helianthus*," "*microbrachia*," "*Kubinjyi*," and "*Cummingii*."

1875. Perrier, Edmond.

Révision de la Collection de Stellérides du Muséum d'Histoire Naturelle de Paris. Arch. Zool. Exp., **4**, p. 265–450. Paris.

The genus *Heliaster* Gray is approved and placed in the Asteriadae (p. 285–286) and a diagnosis is given (p. 299). Later (p. 351) it is given as the fifth genus of the Asteriadae, with four species:

H. microbrachia Xantus. Acapulco.
H. kubiniji Xantus. Acapulco.
H. helianthus (Lam.). Chili.
H. canopus, sp. nov. (Mss. Valenciennes). Juan Fernandez.

The writer considers *microbrachia* the best characterized species, and describes *canopus*, which he says is 70 mm. in diameter and has only 24 rays, and may prove to be the young of *helianthus*. Perrier does not mention *multiradiatus*, but states that he could not find Gray's *cumingii* at the British Museum.

1878. Perrier, Edmond.

Étude sur la Répartition Géographique des Astérides. Nouv. Arch. Mus. d'Hist. Nat., (2) **1**, p. 1–108. Paris.

The geographical distribution of Heliaster is fully discussed in this paper on p. 8, 11, 75, 76, 98–100. By a curious slip of the pen on p. 43, Heliaster is said to be peculiar to "le côte orientale" of America, and the same slip is repeated with reference to Pycnopodia.

1878. Viguier, M.

Anatomie Comparée du Squelette des Stellérides. Arch. Zool. Exp., **7**, p. 33–250, plates 5–16. Paris.

This very important paper deals fully (p. 61, 63, 93, 99, 111–116) with the skeletal anatomy of Heliaster, and discusses its relationship with other starfishes. On plate 6 are given some structural details (figs. 4–12). The conclusion is reached that the peculiarities of Heliaster are sufficient to warrant its elevation to family rank, as the HELIASTERIDAE.

1883. Perrier, Edmond.

Mémoire sur les Étoiles de Mer, recueillies dans la Mer des Antilles et le Golfe du Mexique, etc. Also entitled: Stellérides des Dragages du "Blake." Nouv. Arch. Mus. d'His. Nat., (2) **6**, p. 127–276, plates 1–10. Paris.

The family Heliasteridae is recognized in this work, although the references to it (p. 139, 143, 153, 154) and to the type genus are unimportant.

1885. Lockington, W. N.

Echinodermata; under Lower Invertebrates, Standard Natural History. 6 vols. **1**, Asteroidea, p. 152–161. Boston.

On p. 160 the genus Heliaster (apparently under the "Asteridae") is referred to as having two species, *kubiniji* and *microbrachia*, on the west coast of North America from Panama to Cape St. Lucas.

1886. Ludwig, Hubert.

Dr. Johannes Leunis Synopsis der Thierkunde, etc. 2 vols. **2**. Hannover.

On p. 934 *Heliaster* Gray is given as a genus of Asteriadae, with "mehrere Arten," but *helianthus* (Lam.) Gray is the only one mentioned.

1887. Rathbun, Richard.

Descriptions of the species of *Heliaster* (a genus of starfishes) represented in the U. S. National Museum. Proc. U. S. Nat. Mus., **10**, p. 440–449, plates 23–26. Washington.

In this, the most important paper published dealing with the taxonomy of Heliaster, four species are clearly distinguished, fully described, and admirably figured. The writer considers *H. kubiniji* Xantus (which is spelt

Kubingii throughout the paper) as identical with *multiradiata* Gray, while *H. canopus* Perrier is not mentioned. By a curious slip of the pen, Verrill's paper of 1869 is quoted as Amer. Jour. Sci. instead of Proc. Boston Soc. Nat. Hist.

1889. Ives, J. E.

Catalogue of the Asteroidea and Ophiuroidea in the Collection of the Academy of Natural Sciences of Philadelphia. Proc. Acad. Nat. Sci., 1889, p. 169–179. Philadelphia.

On p. 170 " *H. helianthus* Lam., *microbrachia* Xantus, *multiradiata* Gray (= *Kubiiniji* Xantus) " are listed under the Asteriidae.

1889. Sladen, W. Percy.

Report on the Asteroidea collected by H. M. S. " Challenger " during the years 1873–1876. Rept. Sci. Results Voy. H. M. S. " Challenger." 32 vols. **30**, xlii, 893 pp., 118 plates. Edinburgh and London.

This magnificent monograph contains numerous references (p. xiii, xx, xxi, xxxix, xlii, 555, 556, 671, 686, 690, 701, 812, 813) to the anatomy, systematic position, and geographical distribution of Heliaster and the Heliasteridae. The author is very sceptical as to whether the genus contains more than a single species, and speaks several times of the " so-called " species.

1891. Perrier, Edmond.

Echinodermes I. Stellerides. Mission Scientifique du Cap Horn, **6**. Zoologie, p. K 1–K 198, plates 1–13. Paris.

On p. K 60, K 61, and K 67 are references to the number of rays, and formation of new rays, in Heliaster.

1892. Meissner, Maximillian.

Asteriden gesammelt von Herrn Stabsartz Dr. Sander auf der Reise S. M. S. "Prinz Adalbert." Arch. f. Naturg. Jahrgang 58, **1**, p. 183–190, plate 12. Berlin.

On p. 184 nine examples of *H. helianthus* Lam., with from 30 to 38 rays each, are recorded from Callao, Peru.

1893. Perrier, Edmond.

Traité de Zoologie. Paris.

On p. 781 and 847 are unimportant references to Heliaster.

1894. Lang, Arnold.

Lehrbuch der Vergleichenden Anatomie der Wirbellosen Thiere. — Echinodermata. p. 871–1154. Jena.

On p. 884 is this: 7. Familie. Heliasteridae. Mit zahlreichen, kurzenarmen. Heliaster.

1894. Perrier, Edmond.

Echinodermes: in Exp. Sci. du Travailleur et du Talisman, etc. 431 pp., 26 plates. Paris.

On p. 4 and 27 are unimportant references to the Heliasteridae; on p. 22 Heliaster is said to have "quarante bras et plus," but it is fair to assume that "jusqu'à" is to be understood; on p. 43 Heliasteridae is again referred to and listed as the third family of Forcipulata.

1895. Sluiter, C. Ph.

Die Asteriden-Sammlung des Museums zu Amsterdam. Bijdr. Dierk., **17**, p. 49–64. Amsterdam.

On p. 64 the family Heliasteridae is recognized and *H. helianthus* is listed from Chili.

1895. Leipoldt, Fritz.

Asteroidea der "Vettor-Pisani" Expedition (1882–1885). Zeit. f. w. Zool., **59**, p. 545–654, plates 31–32. Leipzig.

On p. 546–552 are very useful accounts of the distribution and the pedicellariae of *H. helianthus, cumingii, multiradiatus,* and *microbrachius.* Good figures of the jaws of the pedicellariae are given on plate 31, figs. 1 and 2. The peculiar coloration of specimens of *multiradiatus* from the Galapagos Islands is well described. Perrier's record of that species from the "Iles Sandwich" is very properly regarded with doubt.

1896. Plate, Ludwig H.

Zur Kenntnis der Insel Juan Fernandez. Verh. Gesellsch. Erdk. Berlin, nos. 4 und 5, p. 221–229. Berlin.

On p. 224 *H. helianthus* is reported as one of the five starfishes occurring at Juan Fernandez; some further notes are given concerning its occurrence on the South American coast.

1896. Meissner, Maximillian.

Die von Herrn Dr. L. Plate aus Chili und Feuerland heimgebrachten See-Sterne. Arch. f. Naturg. Jahrgang 62, **1**, p. 91–108. Berlin.

On p. 102 *H. helianthus* is reported from Chili as the common starfish of the coast rocks. Two young ones with 12 and 22 rays each are recorded, but, strangely enough, nothing is said as to the size of either. The writer remarks on its being unfortunate that Dr. Plate failed to bring home any specimens of Heliaster from Juan Fernandez, since he reports (1896) *H. helianthus* as being common there, while the specimens upon which Perrier based his species *canopus* (1875) came from that island, and Dr. Plate, by bringing home a series of spec'mens, might have settled the question as to the authenticity of that species.

1897. **Harrington, N. R. and Griffin, B. B.**
Notes upon the Distribution and Habits of some Puget Sound Invertebrates. Trans. N. Y. Acad., **16**, p. 152–165. New York.

On p. 156 is the following mistake: "The commonest sea-star, a gigantic species of *Heliaster*, finds shelter beneath the wharves, etc." Of course, *Pycnopodia helianthoides* is the species referred to.

1899. **Ludwig, H. and Hamann, O.**
Echinodermen: Asteroidea: in Dr. H. G. Bronn's Klassen und Ordnungen des Thier-reichs, etc. **2.** Leipzig.

On p. 566–568 the madreporite of Heliaster is discussed and on p. 713 the family Heliasteridae is accepted with the single genus, Heliaster, and five species, *canopus* Perrier being added to the four described by Rathbun (**1887**).

1900. **Gregory, J. W.**
The Stelleroidea: in Bather's Echinoderma, chap. 13, p. 237–281: in E. Ray Lankester's A Treatise on Zoölogy, Part 3. London.

On p. 258 the family Heliasteridae is accepted with two subfamilies; Helianthasterinae with the single Devonian genus, *Helianthaster* and Heliasterinae with the single recent genus *Heliaster.*

1900. **Ritter, W. E. and Crocker, Gulielma R.**
Multiplication of Rays and Bilateral Symmetry in the 20-rayed Starfish, *Pycnopodia helianthoides* (Stimpson) Proc. Wash. Acad. Sci., **2**, p. 247–274, plates 13–14. Washington.

In discussing the method of ray formation in multiradiate starfishes, there are some references (p. 249 and 263) to Heliaster, based however on assumption and not on investigation.

1902. **Goette, Alexander.**
Lehrbuch der Zoologie. Leipzig.

On p. 319 *Heliaster helianthus,* "mit zahlreichen Armen," is given as an example of the Cryptozonia.

1902. **Kingsley, J. S.**
Hertwig's Manual of Zoölogy. New York.

On p. 337 *Heliaster* is given as an example of a starfish with numerous well developed rays and "ambulacra in four rows."

1902. **Clark, Hubert Lyman.**
Echinodermata: in Papers from the Hopkins-Stanford Galapagos Expedition, 1898–99. Proc. Wash. Acad. Sci., **4**, 521–531. Washington.

On p. 523–524 are some notes on *H. cumingii* and *multiradiatus.*

1903. Delage, Yves et Herouard, Ed.
Traité de Zoologie Concrète. 9 vols. **3.** Les Echinodermes. Paris.

On p. 103 is this:
7 Fam.: Heliasterinae [*Heliasteridae* (Viguier); p. p. *Forcipulata* (Perrier)] — Heliaster (Gray). Bras 25 au moins. Helianthaster (Römer) (Dev.).

1906. Fisher, Walter K.
The Starfishes of the Hawaiian Islands. Bull. U. S. Fish Commission for 1903, part 3, p. 987–1130, plates 1–49. Washington.

On p. 989, 994, and 998 are brief references to *H. multiradiatus*, and on p. 1002 the family Heliasteridae is included in the Key. On p. 1104 *H. multiradiatus* is admitted to the Hawaiian fauna on the strength of Sladen's statement, but serious doubt is expressed as to the validity of the record.

As a result of the examination of this literature, our present knowledge of Heliaster may be briefly summarized as follows: Six species have been described, of which one (*kubiniji* Xantus) is commonly considered identical with another (*multiradiatus* Gray), while a third (*canopus* Perrier) is regarded as possibly the young of a fourth (*helianthus* Lamarck), and by some writers the remaining two are not considered as really distinct. The geographical limits of the genus are fairly well known, but there is still some question about the limits of the several species. The external morphology, including the pedicellariae, is very well known and the skeletal characters especially of the oral surface have been well worked out. But the internal anatomy is practically unknown, and almost nothing is recorded of the habits; absolutely nothing of the development. The amount of variability within a single species is little understood and almost nothing is known of the formation of the new rays in passing from the young stages with relatively few, to the older condition with very numerous, rays. Finally the relationship to other genera is most imperfectly understood, although there is general agreement in placing the genus apart in a family by itself.

Systematic.

We naturally turn first of all to an investigation of the number and validity of the species which Heliaster contains, and the material at hand enables us to settle all of the disputed questions in regard to this matter. In his admirable report on the Heliasters of the United States

National Museum, Rathbun (1887) has shown beyond question the existence of at least four well-marked species, and the present investigation confirms his conclusion. But Rathbun had no material from Juan Fernandez, and consequently does not refer to *canopus* Perrier, while he had only a few specimens from the Galapagos, and these he naturally assigns to the species named by Gray, which came from Hood's Island. The material now available, includes a fine series of adults and young from Juan Fernandez, which confirms Perrier's opinion that the species occurring at the island is quite different from *helianthus* and is entitled to recognition as a distinct species, *canopus.* The number of specimens from the Galapagos makes it possible to show that the Heliasters of that group of islands present certain characters in which they are obviously and apparently constantly different from their nearest allies on the American coast. Of course there is room for difference of opinion as to whether these characters are sufficiently tangible and constant to warrant calling the island forms separate species, but since the characters are associated with sharply distinct geographical areas (for Heliaster is littoral in the extreme) and since the island forms were long ago named by Gray, and one of the mainland near allies by Xantus, it seems better to give the other mainland ally a name, and thus recognize seven species of Heliaster. In no other way can the apparent plasticity of the genus and the results of isolation be so well brought out.

Heliaster Gray.

Asterias; section e, Heliaster Gray, 1840. Ann. Mag. Nat. Hist., 6, p. 179.

Heliaster (used without comment as a generic name) Xantus, 1860. Proc. Acad. Nat. Sci. Phil., p. 568.

Heliaster Dujardin et Hupé, 1862. Hist. Nat. Zoöph. Echin., p. 343.

Asterias; section f, Heliaster Gray, 1866. Syn. Starf. Brit. Mus., p. 2.

Heliaster Perrier, 1875. Arch. Zoöl. Exp., 4, p. 299.

Since Perrier's diagnosis the genus Heliaster Gray has been universally recognized.

Gray's diagnosis was as follows: —

Body discoidal, divided at the edge into numerous short tapering rays; the series of spines near the ambulacral series rather crowded, large, and elongated.

To this characterization, Perrier added nothing, but Viguier (1878) suggested as additional features the funnel-shaped depression in which the mouth is placed, the fragmentation of the madreporite, the double interbrachial walls, and the fused condition of that interradial plate which he calls the "odontophore." Unfortunately the first and last of these characters are of doubtful value, and the

second is not true of all Heliasters. The third, although quite characteristic, is not confined to this genus. Accordingly, the following diagnosis of the genus, which represents our present knowledge, does not differ markedly from that of Gray: —

Disc large, not set off externally from the fused bases of the rays, little elevated, with reticulated abactinal skeleton, and more or less numerous spines, pedicellariae, and papulae. Rays numerous, more than 20 in normal adults, more or less united at base, so that only a relatively small part (15–70%) is free.[1] Adambulacral armature variable, usually single, sometimes double, especially near tip of ray; spines of alternate plates often of two sharply contrasted sizes, especially near base of ray. Pedicels arranged in two more or less zigzag rows, so that near middle of ray they are, as a rule, distinctly quadriserial. Forcipate and forficate pedicellariae both present, the latter often of two quite distinct sizes. Interbrachial septa double and well developed, expanding at inner (proximal) end and uniting laterally more or less extensively, to form a discobrachial wall, so that the cavity of the disc is almost completely separated from the cavities of the rays. (See plate 6, fig. 1).

This well-marked genus is easily distinguished by the number of rays alone, from all other starfishes except *Pycnopodia* and *Labidiaster*. From the former it is readily separated by the well-developed abactinal skeleton, the large disc and the fused rays. From Labidiaster it differs in the fused rays and quadriserial pedicels. The double interbrachial septa with the remarkable discobrachial wall are internal features, distinguishing Heliaster from either genus. — The distribution of Heliaster is remarkably restricted as it occurs only in very shallow water along the tropical and subtropical coasts of the eastern Pacific Ocean. I can find no record of a specimen being taken with a dredge or trawl, so that they are apparently littoral starfishes in the strictest sense of that term. They occur upon and among rocks in the neighborhood of low-water mark. The most northern point of their range, as shown by the specimens before me is San Luis Gonzales Bay, Gulf of California, in latitude 29° 15′ N., while the southern extreme on the mainland appears to be in the vicinity of Valparaiso, 33° 2′ S. lat. There are no published records of the occurrence of Heliaster, either north or south of these limits, and it is not recorded from any of the outlying islands, save Juan Fernandez, 33° 38′ S. lat., and the Galapagos, on the equator. — Nothing has been recorded of the habits of Heliaster, but preserved specimens show that the food consists very largely of small mussels, limpets, and acorn-shells (barna-

[1] In estimating the percentage of ray that is free, the length of the free portion is divided by R. (*i. e.*, the distance from centre of abactinal surface of disc to tip of ray) as it is not feasible to measure the actual length of ray. Consequently the free part is really a larger proportion of the ray itself than the percentages herein given would seem to indicate. It should also be noted that the rays are fused to a much greater extent relatively in adult than in young specimens; very young individuals often have twice as much free ray as adults of the same species.

cles). In two cases a half of a small fish was found in the stomach, but it is probable that the fish were found dead on the rocks among the mollusks and barnacles on which the Heliaster was feeding. — Parasitic gastropods (*Stylifer*) are common on specimens of Heliaster from the Galapagos Islands and occur not infrequently on specimens from the South American coast.

The following keys show the characters by which the seven species here recognized are to be distinguished. The first is wholly morphological and shows the species in what is probably their natural relationship. The second is quite artificial and takes into account the geographical distribution; it may be found useful in identifying specimens from known localities, where a large series of individuals is not available for comparison. In using these keys, it must be borne in mind that the number of rays is fewer in young individuals than in adults and that (as already mentioned) they may be free for a much greater proportion of their length. Consequently specimens under one hundred millimeters in diameter cannot always be certainly identified by means of these keys alone.

Key to the Species.

A. Rays free for 30 per cent of their length, or more.

  B. Rays 30 or more, free about 35 (30–40) per cent of their length . . . . *helianthus*

  B. Rays 28 or fewer, free for 40–70 per cent of their length.

    C. Spines on abactinal surface of disc numerous, little or not at all capitate, smaller than those which form conspicuous marginal series on abactinal surface of rays; between these marginal series is a median series with a lateral series on each side; latter generally inconspicuous and made up of very small spines; marginal series converge on disc, confining median series to ray . . . . *canopus*

    CC. Spines on abactinal surface of disc comparatively few, many of them usually conspicuously capitate and larger than those of marginal series of rays; between latter are three or more not very clearly defined series of which the median is most conspicuous and continues inwardly onto the disc.

      Rays free for more than half their length, 50–70 per cent; color, abactinally, pale yellowish mottled with blackish, the rays more or less distinctly banded; spines, pedicellariae, and madrepore plate, light yellowish . . . . *multiradiatus*

      Rays free usually for less than half their length, 40–55 per cent; color, abactinally, deep purplish; spines, pedicellariae, and madrepore plate, more or less deep yellow; rays sometimes indistinctly banded . *kubiniji*

AA. Rays free for less than 30 per cent of their length, rarely less than 30 in number in adults.

B. Abactinal surface covered with numerous small, often subacute, rarely capitate, spines of nearly uniform length, not arranged in radiating series except on rays, where five such series are usually more or less evident . . . . . . *microbrachius*

BB. Abactinal surface with rather large, often capitate spines, arranged in more or less distinct radial series, especially on rays, where three such series are very evident.

Abactinal spines not very numerous, 15–20 per sq. cm. where thickest, more or less cylindrical, often subacute, rarely distinctly capitate; pedicellariae often wanting on actinal surface; rays often free for more than 20 per cent of their length . . . . *cumingii*

Abactinal spines more numerous, 25–50 per sq. cm. where thickest, low, usually capitate; pedicellariae frequent on actinal surface; rays seldom free for more than 20 per cent of their length . . . . *polybrachius*

Artificial Key to the Species.

A. Rays more than 30, rarely as few as 27 or 28.

B. Rays free for 30 per cent of their length or more; west coast of South America . . . . *helianthus*

BB. Rays free for less than 30 per cent of their length.

C. Abactinal surface with very numerous small spines, rarely capitate; five subequal series on rays; west coast of Mexico and Central America . . . . . *microbrachius*

CC. Abactinal surface with fewer, larger, capitate spines; three series on rays.

Abactinal spines not crowded, little or not at all capitate; Galapagos Islands . . . . *cumingii*

Abactinal spines numerous, often crowded, especially near margin of disc, usually distinctly capitate; west coast of tropical South America . . . . *polybrachius*

AA. Rays never more than 28.

B. Abactinal surface of disc with spines smaller than the marginal series on rays; diameter of adult 80–120 mm.; Juan Ferdandez . . . . *canopus*

BB. Abactinal surface of disc with large, often capitate spines; diameter of adult 110–180 mm.

Rays free for 40–55 per cent of their length; west coast of Mexico and Central America . . . . *kubiniji*

Rays free for 50–70 per cent of their length; Galapagos Islands . . . . *multiradiatus*

Heliaster helianthus (LAMARCK).[1]

Plate 3, Fig. 1; Plate 7, Figs. 1-7.

Tournesol Davila, 1767.
Asterias helianthus Lamarck, 1816.
Stellonia helianthus Agassiz, 1835.
Asteracanthion Helianthus Müller and Troschel, 1842.
Heliaster helianthus Dujardin and Hupé, 1862.

Description. — Rays 30–40, averaging (51 individuals) 34.8; about 35 (29–43) per cent of ray, free. R=75–150 mm.; r=45–90 mm. Breadth of ray at base, 8–15 mm. R=7–9 br. Rays more or less flattened both actinally and abactinally, angular with nearly vertical sides, commonly tapering but often abruptly blunt-pointed, becoming more nearly terete near tip. Disc large, little or not at all elevated above base of rays; in a specimen with R=150 mm. the vertical diameter is only about 30 mm.[2] Abactinal surface covered with a stout, reticulated skeleton having rather small meshes. Skeletal plates with numerous spines of variable size, form, and arrangement. There are usually three well-marked series on each ray and these continue inward onto the disc far beyond the base of the ray; the median row is the most conspicuous and includes numerous clusters of more or less capitate spines; the lateral rows contain fewer spines, commonly arranged in a single series, which may be larger or smaller, and more or less capitate, than those in the median row. The lateral rows are nearly parallel with each other and remain separate, so that the median series is also present proximally. On the central part of the disc, the prominent and usually capitate spines do not show a serial arrangement but they are commonly grouped in more or less irregular, short lines, which form a sort of imperfect reticulation. In some specimens this network is quite distinct, the meshes being three or four millimeters in diameter and each side of a mesh consisting of a crowded single series of from three to seven spines. In other specimens no reticulation is evident, the spines being irregularly scattered, although here and there a few tend to form a crowded, linear series. Specimens sometimes occur in which no arrangement of the abactinal spines is evident even on the rays, but they appear to be scattered irregularly everywhere. Besides the conspicuous spines, smaller and more slender ones frequently occur abactinally, and pedicellariae, chiefly of the forcipate type, are more or less abundant, especially near the tips of the rays, while papulae occur everywhere. — Sides of rays with three or four longitudinal series of spines which are usually very

[1] No attempt is made to give complete synonymies of the seven species, as that would involve a virtual repetition of the bibliography already given. Only such names are listed as show some difference from the one originally given or the one herein accepted. It should be noted in passing that Gray never used Heliaster as a generic name and never published it in direct connection with any specific name; consequently it is not correct to write "*Heliaster helianthus* (Lam.) Gray" as has often been done; if two authors are to be referred to, the name should be written as Sladen gives it, "*Heliaster helianthus* (Lam.) Dujardin and Hupé."

[2] It is useless to attempt to distinguish externally the true limits of the disc, and the term is used in these descriptions to include the fused basal portion of the rays.

markedly compressed, among which are numerous pedicellariae and papulae. — Actinal surface of disc almost entirely occupied by ambulacra, adambulacral spines, pedicellariae, and papulae; interbrachial areas reduced to a minimum. — Adambulacral plates with typically a single, conspicuous, erect spine. In young specimens these may all be of equal size, but in adults, near the middle of the ray, larger and smaller spines alternate, so that every other plate has a small spine standing between the larger spines of the neighboring plates. The smaller spines are commonly almost or quite within the furrow. In some specimens the small spines are wholly wanting proximally so that only every other plate carries a spine. As a rule the spines are all of a nearly uniform size near the tip of the ray. On the distal half of the ray, some of the adambulacral plates often carry two spines, one behind the other. Beginning just proximal to the base of the ray and running outward to the tip, a series of large spines is found just outside the adambulacral series, and this is followed by one or two more, each series slightly shorter than its predecessor. These additional actinal spines differ greatly in number and size in different specimens, apparently increasing with the age of the animal. The adambulacral spines on the middle and proximal part of the ray are the largest spines of the actinal surface and may be as much as five millimeters long. Along the sides of the ambulacral furrows, among the adambulacral and other spines, are numerous pedicellariae, chiefly of the forficate type and of two quite distinct sizes (Plate **7**, figs. 2, 3); but the size and abundance of the pedicellariae vary greatly in different individuals. — At the centre of the actinal surface occurs the very large buccal membrane, thin, smooth, and conspicuous, with the mouth at the centre. The membrane in a large specimen (R=150 mm.) is 35 mm. across and the mouth is ten millimeters in diameter. Each oral (adambulacral) plate carries two or three short spines arranged side by side more or less horizontally, the innermost the longest, the others successively shorter. The actinal surface shows more or less of a tendency to become abruptly and deeply concave at the centre, so that the proximal portions of the ambulacra are almost vertical, the adambulacral spines thus lying horizontally and the oral spines vertically. This tendency is much more marked in some specimens than in others; thus, in a specimen with R=105 mm., the buccal membrane is 20 mm above the horizontal portion of the actinal surface of the rays, while in another specimen with R=150 mm. the depression is no deeper; and in a third specimen with R=48 mm., the vertical distance to the buccal membrane is only five millimeters. As no observations on the living animal have yet been recorded, it is impossible to say whether this buccal depression has any physiological importance or not. It is interesting to note however that in adult specimens where the depression is well marked, the adambulacral spines on its sides are smaller and less prominent, and the pedicels longer and more prominent, than elsewhere on the actinal surface. — Pedicels in a zigzag row on each side of each ambulacrum, scarcely crowded enough to make them quadriserial; proximally in adults and still more so in the young, they are distinctly biserial. Madreporite single; small, slightly convex and irregularly furrowed in young specimens, usually becoming broken up into a number of fragments in adults; even small specimens may show this fragmentation to some extent. — Color [1] of abactinal surface dark (gray, brown, blackish, or black), rarely more or less variegated with

[1] The color of living Heliasters has never been described; in all the descriptions here given, the colors referred to are those of alcoholic and dried specimens.

light colored blotches ; spines and madreporite, yellowish or whitish ; actinal surface yellowish, the pedicels darker than the spines.

Range. — San Lorenzo and Manta, Ecuador (Rathbun); Payta, Peru (M. C. Z. and U. S. N. M.) ; Ancon, Peru (Rathbun) ; Callao, Peru (Meissner); Arica and Iquique, Chili (Plate) ; Mejillones, Chili (M. C. Z.) ; Caldera, Chili (M. C. Z) ; Copiapo, Chili (Leipoldt) ; Guasco, Chili (Say) ; Coquimbo and Valparaiso, Chili (Plate). — How far north of the equator this species occurs we have no definite information; but there can be little question that Stimpson's (1857) record of it from Mazatlan, Mexico, is based on a specimen of *microbrachius*. It probably does not reach Panama Bay, or the many collectors who have been there would have found it, and by similar argument we may say it does not range to any great distance south of Valparaiso. It has not been taken at any of the outlying islands.[1] We are justified, therefore, in considering its range to be as follows : —

Mainland coast of western South America from northern Ecuador (about 2° N. lat.) to Valparaiso, Chili (33° 2′ S. lat.).

Remarks. — As this is the longest known and the largest species, it is probably most often seen in museums, and most frequently referred to in literature. The compound nature of the madreporite has been spoken of by many writers, but examination of a large series of specimens shows that the madreporite is not different, early in life, from that of Asterias, and not even in adults is it always broken up, for it may remain single and without peculiarities throughout life. Young specimens of *helianthus* usually have the rays much more blunt and less tapering than adults, and the three longitudinal series of spines on the abactinal side of each ray are usually very distinct. — Among the specimens sent me from the National Museum is an interesting individual (No. 21947), about 120 mm. in diameter, and having 32 rays, labelled "Loc. ? Albatross, 1888." The further information is given in a list of the Heliasters sent, "Found in bottom of tank; may belong to one of above lots;" the "above lots" referred to are from the Galapagos Islands and the Gulf of California. Although too young to make identification certain, the specimen is apparently a young *helianthus*, as shown by the form and arrangement of the abactinal spines, the madreporite, and the long, free (33–40 per cent) rays. The locality of this specimen is therefore a matter of great interest, for the "Albatross" in 1888 made no shore collections between Lota, Chili (37° S. lat.), and Panama, save at the Galapagos Islands, and all of these places are well outside the known range of *helianthus*.

Material examined : —

15 specimens.	Mejillones, Chili.	M. C. Z.	collection.
10 "	Payta, Peru.	"	"
23 "	Caldera, Chili.	"	"
2 "	"Peru."	"	"
?1 specimen	Loc.?	U. S. N. M.	"
51 specimens	5 localities.		

[1] Plate's (1896) reference to *helianthus* at Juan Fernandez is probably based on specimens of *canopus*.

Heliaster canopus Perrier.

Plate 3, Fig. 2; Plate 8, Fig. 7.

Heliaster canopus Valenciennes. Perrier, 1875.
Heliaster canopus (Val., MS.) Perrier. Sladen, 1889.

There is no good reason why Valenciennes' name should be associated with this species any longer, for his manuscript museum name has no standing. Perrier was the first and only describer of the species.

Description. — Rays, 20–27, averaging (27 individuals) 24; about 53 (47–60) per cent of ray free. R = 30–60 mm.; r = 15–30 mm. Breadth of ray at base, 4–7 mm. R = 7–8 br. Rays somewhat flattened, or a little arched abactinally, rather angular, with blunt and rounded tips. Disc moderately large, flat, or a little arched. Abactinal skeleton rather stout and with small meshes. Abactinal spines numerous, small, rather slender, and not at all capitate, without definite arrangement on disc, but appearing in distinct series on rays. Marginal series of ray contain largest abactinal spines; median series somewhat smaller. Between marginal and median series, a lateral series of very small spines is often present. The marginal series tend to converge as they pass on to the disc, and thus separate the median and lateral rows from the spinulation of the disc; this arrangement is usually evident, but is much more marked in some specimens than in others. — Sides of ray with two or three series of long, compressed spines. Actinal surface essentially as in *helianthus.* Pedicellariae fairly common, especially towards tip of rays abactinally, chiefly forcipate; large forficate ones rather rare and smaller than in *helianthus.* Madreporite usually simple and convex, rarely flattened and fragmented. — Color of abactinal surface deep purplish-black; spines whitish; actinal surface and madreporite yellow; pedicels brownish-yellow.

Range. — Juan Fernandez Islands (M. C. Z.).

Remarks. — This interesting little species is remarkably well characterized, and can be very readily distinguished at a glance. Perrier (1875) thought it possible that it was the young of *helianthus*, but the large series of specimens collected by the "Hassler" has made it possible to show that this is not the case. Young specimens of *helianthus* have more than 30 rays by the time they are 70 mm. in diameter, whereas the largest specimen of *canopus*, 120 mm. in diameter, has only 20, and there is only one specimen with as many as 27. The difference between *canopus* and a young *helianthus* in the abactinal spinulation is well shown on plate 3. Finally, it is important to note that in the larger specimens of *canopus* the reproductive organs are fully developed, showing their sexual maturity in spite of their small size. — An interesting point with reference to this species is that 17 of the specimens (or more than 60 per cent) have an even number of rays, whereas in *kubiniji* and *multiradiatus*, the two other species with relatively few rays, only 41 out of 127 (or less than 33 per cent) have an even number. Now in *helianthus* 56 per cent have an even number of rays, and it would seem as though the condition in *canopus* is further confirmation of the view that this

little species is more nearly related to *helianthus* than to the species with relatively few rays.

Material examined: — 27 specimens, Juan Fernandez, M. C. Z. collection.

Heliaster multiradiatus (Gray).

Plate 4, Fig. 1.

Asterias multiradiata Gray, 1840.
Heliaster multiradiatus Dujardin and Hupé, 1862.
Heliaster multiradiata Verrill, 1867.

Description. — Rays 21–27, averaging (10 individuals) 23.8; about 60 (50–70) per cent of ray free. R = 60–100 mm.; r = 25–47 mm. Breadth of ray at base, 6–12 mm. R = 8–10 br. Rays more or less distinctly cylindrical, sometimes slightly flattened and rather angular abactinally, especially near middle. Disc moderate, more or less distinctly and abruptly elevated at centre. Abactinal skeleton moderately stout, reticulate, with rather small meshes. Abactinal spines not very numerous, about 10–16 per sq. cm., moderately stout, high, especially on disc, and more or less cylindrical, sometimes thickened, clavate or capitate at the summit. No evident arrangement on disc, but on rays a median series, with a lateral and marginal series on each side (five series in all), can generally be clearly distinguished, though sometimes there appear to be six series, or again only four. The largest spines are on disc and at base of ray, the smallest near tip of ray; the median series is usually somewhat larger than the others. — Sides of ray with two series of compressed spines, which are usually shorter than the adjoining actinal series. Actinal surface much as in *helianthus* and the other species, but the adambulacral armature is somewhat different, for the large spines do not alternate with small ones, but are practically uniform in size, and on many of the plates a second smaller spine stands on the inner edge, thus making the armature of the furrow double. In some specimens nearly the whole series is double, while in others two spines are to be found only on scattered plates. Occasionally three spines occur on a single plate. The larger spines are about three millimeters long, quite slender, and nearly cylindrical. Outside of the adambulacral series are two rows of actinal spines, the lower of which consists of spines longer and heavier than the adambulacral, while the upper are somewhat smaller. These two series, but especially the lower, extend inward well onto the interbrachial area. Towards the tip of the ray all of the large spines become greatly reduced, so that the 15–17 series which surround the tip are of nearly uniform size, though the adambulacral and adjoining series are still distinguishably larger. Buccal depression as in *helianthus*. — Pedicels not very numerous or crowded, so that they are not truly quadriserial at any point. Pedicellariae mostly small, numerous, especially on abactinal side of rays near tip; sometimes very large forficate pedicellariae occur on the actinal surface. Madreporite rather small, usually simple and convex, very rarely showing any trace of fragmentation. — Color of abactinal surface, light gray, yellowish, or whitish, irregularly blotched with dark gray or blackish; on the rays the dark blotches appear as irregular cross-bands; spines whitish, yellowish, or brownish; actinal surface mostly light yellow or whitish, but interbrachial areas and outer side of large adambulacral spines on proximal half of rays tend to become blackish, and in most specimens there is a striking contrast between the inner and the

outer sides of the adambulacral series, and between the basal and distal halves of each adambulacral spine, on its outer side; oral spines usually dark, at least on aboral side; madreporite white or yellow.

Range. — Hood's Island (Gray); Chatham Island (U. S. N. M.); Albemarle Island (M. C. Z.); Charles Island (M. C. Z.). Confined to the Galapagos Islands. — The reported occurrence of this species in the Hawaiian Islands is to be accounted for as follows: — In 1867 Verrill described a specimen of *kubiniji*, which he said was obtained with other Panamic species from Mr. Pease at the Sandwich Islands, but probably came from Acapulco or Mazatlan, Mexico. Perrier (**1878**), ignoring or failing to understand the latter half of Verrill's statement, gives "Iles Sandwich" as one of the localities for *kubiniji*. Sladen (**1889**), accepting Rathbun's view that *kubiniji* is a synonym of *multiradiatus*, and also evidently accepting Perrier's list of localities at its face value, gives Sandwich Islands as a habitat of *multiradiatus*. On the strength of Sladen's word, Fisher (**1906**) includes *H. multiradiatus* in his list of Hawaiian starfishes, but he very properly expresses serious doubt as to any Heliaster occurring at Hawaii.

Remarks. — Verrill (**1867**) in speaking of *kubiniji* pointed out that Gray's description of *multiradiatus* did not fit specimens from Mexico, and the two species were regarded as distinct until Rathbun (**1887**) compared two specimens from Chatham Island with a large series from Mexico, and reached the conclusion that they were identical, and that *kubiniji* was therefore a synonym of *multiradiatus*. Sladen (**1889**) adopted that conclusion, and it has since been very generally accepted. In 1895 Leipoldt, referring to five specimens from Chatham Island, describes what he calls their "peculiar" coloration, his specimens agreeing well with typical *multiradiatus*, the coloring of which had never previously been described, for curiously enough neither Gray nor Rathbun make any reference to the color. Dr. Rathbun has kindly sent me, among the Heliasters from the National Museum, the two specimens from Chatham Island, on which his opinion was based. I find they agree in all essentials with the other Galapagos specimens before me, and there will be no question that to them belongs the name *multiradiatus*. After a comparison of these specimens with a very large series of *kubiniji* from Mexico I am obliged to disagree with Rathbun's conclusion that they are all one species. No one will question the close relationship between the Galapagos and Mexican forms, and it is simply a matter of personal opinion whether it is better to emphasize the relationship by uniting them under one name, or to emphasize by distinct names the differences which have arisen in completely separated geographical areas and which are obviously and reasonably constant. The latter course seems to me preferable. The differences between the two can better be discussed under *kubiniji*, and only one or two other points need to be referred to here. Both species show great diversity in the length of the different rays in a single individual, old specimens often having only two or three rays of exactly the same length. As an illustration of this fact, the following measurements (in millimeters) of the 25 rays of an excellent specimen of *multiradiatus* may be given, beginning with the ray to the left of the madrepore and going clockwise: 72, 71, 70, 69, 51, 57, 65, 68,

64, 67, 73, 68, 71, 69, 72, 40, 42, 71, 66, 44, 75, 74, 72, 45, 66. Of the 25 rays, one is 75 mm., one is 74, one is 73, three are 72, three are 71, one is 70, two are 69, two are 68, one is 67, two are 66, one is 65, one is 64, one is 57, one is 51, one is 45, one is 44, one is 42, and one is 40 mm. long. Besides this diversity in length, it is not an easy matter to say just what proportion of the ray is free, for, while of one ray 70 per cent may be free on one side and 65 on the other, another ray may be only 50 per cent free on each side. To determine the point satisfactorily four or five of the longest rays should be measured, the measurements added together and divided by four or five, as the case may be, the quotient being the average R. Then measure the free portion on each side, add, and divide by eight (or ten), the quotient being the average free portion. Dividing this by the average R gives the percentage of ray that is free. Adopting this plan for one of the best specimens of *multiradiatus*, we get these figures : —

$$83 + 83 + 82 + 76 + 80 = 404 \text{ mm.} \div 5 = 80.8 \text{ mm.} = \text{R}.$$

$$50 + 51 + 50 + 53 + 46 + 44 + 47 + 48 + 46 + 45 = 480 \text{ mm.} \div 10 = 48 \text{ mm.} = \text{free portion.}$$

$$48 \div 80.8 = .59 \therefore 59 \text{ per cent of ray is free.}$$

With the other five species of Heliaster it is not necessary to go to such trouble, as all the rays are, in normal specimens, of approximately the same length. — The specimens of *multiradiatus* from Chatham Island are notable for the large abactinal spines, which are as heavy as in most specimens of *kubiniji*. One of the specimens is further remarkable for the fact that although very large (R = 100 mm.) there are only 15 developed rays and two of these are very small; there is also a very rudimentary ray 6 mm. long, at one point on the abactinal surface. Careful examination shows that this individual was at some time badly injured, nearly bisected in fact, and has only imperfectly made up its loss.

Material examined: —

3 specimens.	Albemarle Island.	Leland Stanford Jr. Univ. collection.	
5 "	Charles "	M. C. Z.	"
2 "	Chatham "	U. S. N. M.	"
1 specimen	Albemarle "	M. C. Z.	"
11 specimens.	3 localities.		

Heliaster kubiniji Xantus.

Plate 4, Fig. 2; Plate 5, Fig. 2; Plate 6, Fig. 1: Plate 7, Figs. 8–10; Plate 8, Figs. 1–6.

Heliaster kubiniji Xantus, 1860.
Heliaster Kubiniji Verrill, 1867
Heliaster Kubinjii Lütken, 1871.
Asterias Kubinjyi Lütken, 1872.
Heliaster Kubingii Rathbun, 1887.
Heliaster Kubinijii Ives, 1889.

Description. — Rays 21–28, averaging (90 adults) 23; about 47 (40–55) per cent of ray free. R = 60–107 mm.; r = 30–60 mm. Breadth of ray at base, 6.5–15

mm. R = $6\frac{1}{2}$– $9\frac{1}{2}$ br. Rays more or less cylindrical, sometimes slightly flattened and angular abactinally, but usually tapering more sharply than in *multiradiatus.* Disc moderate, more or less distinctly and abruptly elevated at centre. Abactinal skeleton and spines as in *multiradiatus,* but median and lateral series of spines on ray more distinct, usually with more numerous, and stouter and more capitate spines. Space between lateral and marginal series wider than between lateral and median, and usually conspicuous. Spines on disc often very stout and much thicker at top than at base, sometimes two to two and one half millimeters across, not infrequently with the broad tip distinctly concave and more or less notched in the margin. — Sides of ray and actinal surface as in *multiradiatus,* except that the spines of the series outside the adambulacral row are much stouter, and are often compressed and truncate or even clavate. The actinal aspect of the ray is thus quite as different in the two species as the abactinal. Pedicellariae, pedicels, and madreporite, as in *multiradiatus.* — Color of abactinal surface deep purplish-black; spines more or less deep yellow; pedicellariae yellowish, often so numerous as to give the distal half of the ray a nearly uniform yellow color; occasionally the rays have a banded appearance as in *multiradiatus,* but not so distinct as in that species, and seemingly due in large part to unequal distribution of the pedicellariae; actinal surface deep yellow with pedicels very dark, often blackish; adambulacral spines often blackish at base on the outer side, and those near mouth are sometimes very dark for their whole length; madreporite deep yellow.

Range. — San Luis Gonzales Bay, Lower California; Guaymas, Mexico; and San Juan, L. C. (U. S. N. M.); Margarita Bay, L. C. (Perrier); Magdalena Bay, L. C. (Ives); Puerto Balandia, La Paz and Pichilingue Bay, L. C. (U. S. N. M.); Altata, Mexico (Lutken); Mazatlan, Mexico (M. C. Z.); Cerro Blanco, Cape St. Lucas, L. C. (U. S. N. M.); Acapulco, Mexico (M. C. Z.); and Macuoha, Nicaragua (Ives). — A specimen in the National Museum labelled "Guanajuato, Mexico," was probably purchased by the collector in that inland city at a curiosity shop. Another specimen labelled "Colorado Desert" is badly worn, as though by sand, and looks as though it might have been picked up in the desert, though how it came there would be hard to decide. — There seems to be no record for this species south of Nicaragua, so that its range is apparently confined to the western coast of Central America and Mexico, between 10° and 30° N. lat.

Remarks. — This is a very easily recognized species, as the small number of rays, free for nearly half their length, the large abactinal spines and the coloration combine to distinguish it at a glance from all, except *multiradiatus.* From that species it is separated not merely by the color, which is quite distinctive, but especially by the appearance of the rays, which are less slender, less largely free, and have stouter spines. The differences are all shown in the figures given (Plate 4), where even the contrast in color is plainly indicated. Yet *kubiniji* shows great diversity even in specimens from one locality, the spines on the abactinal surface, particularly those forming the median series on the rays, varying greatly not only in actual but in relative size. There is also much variety in the relative breadth of the rays, but it must be admitted that it is only small specimens (R = less than 70 mm.) which have the rays more than 8 times as long as thick. There is

less diversity in color, for although the rays are sometimes transversely banded, *kubiniji* is always darker than *multiradiatus*, the yellow being much deeper, often becoming quite brown. Comparatively little variation in the amount of ray that is free is shown, the very great majority of specimens having half or a trifle less.

Material examined: —

42	specimens.	Acapulco, Mexico.	M. C. Z.	collection.
20	"	Mazatlan, "	"	"
5	"	Loc.?	"	"
15	"	Cape St. Lucas, L. C.	U. S. N. M.	"
16	"	Pichilingue Bay, L. C.	"	"
5	"	"Lower California."	"	"
4	"	La Paz, L. C.	"	"
3	"	Guaymas, Mexico.	"	"
2	"	San Luis Gonzales Bay.	"	"
1	specimen	"Gulf of California."	"	"
1	"	San Juan, L. C.	"	"
1	"	"Guanajuato, Mexico."	"	"
1	"	"Colorado Desert."	"	"
116	specimens.	13 localities.		

Heliaster microbrachius Xantus.

Plate 1; Plate 7, Fig. 11.

Heliaster microbrachia Xantus, 1860.
Asterias helianthus Stimpson, 1857. ?
Asterias microbrachia Lütken, 1871.
Heliaster microbrachius Leipoldt, 1895.

Description. — Rays 27–44, averaging (37 individuals) 34.7; about 25 (20–30) per cent of ray free. $R = 60–125$ mm.; $r = 45–95$ mm. Breadth of ray at base 8–15 mm. $R = 7–8$ br. Rays more or less flattened abactinally, tapering rather sharply to a blunt point. Disc very large, somewhat elevated in well-preserved specimens, but not abruptly so. Abactinal skeleton stout, closely reticulated, with small meshes. Abactinal spines very numerous, 35–50 or even more per sq. cm., small, usually low, more or less cylindrical and without definite arrangement. In some large specimens the spines show a slight tendency to be capitate, and in many cases they are very evidently compressed. In some individuals the spines on the rays form five fairly distinct series, and these can be followed inward for a variable distance onto the disc. At the edge of the disc the marginal series of adjoining rays are sometimes very clearly separated by a bare space about 2 mm. broad, but in full-grown specimens this arrangement is not usually distinct. — Sides of ray with two series of compressed spines. Actinal surface very much as in *helianthus*, but pedicellariae are as a rule less frequent, and the reduction of the adambulacral armature reaches its extreme, for in large specimens only every other adambulacral plate bears a spine until the distal half or even third of the furrow is reached, and even at the extreme tip of the ray it is rare to find a plate with two spines. — Pedicels rather numerous, distinctly quadriserial at the middle of the ray. — Madreporite rather small, often concave, and usually fragmented. — Color of abactinal surface purplish- or grayish-black; spines deep yellow or whitish; actinal surface whitish,

yellowish, or brownish, with pedicels much darker than spines; madreporite brown.

Range. — Asuncion Island and Cape St. Lucas, L. C. (U. S. N. M.); Margarita Bay, L. C. (Perrier); Magdalena Bay, L. C. (Ives); Lequina Bay, L. C. (M. C. Z.); La Paz, L. C. (Perrier); Altata, Mexico (Lütken); Mazatlan and Acapulco, Mexico (M. C. Z.); Panama (M. C. Z.); and Pearl Island, Panama (Verrill). — Ives (1889) lists a specimen from Chili, and there is a dried specimen in the collection of the Museum of Comparative Zoölogy labelled "Chili, Hassler Expedition." The latter agrees perfectly with the numerous dried specimens from Acapulco, collected by the "Hassler," and I have no doubt it is one of the same lot, which has received an erroneous label by mistake. It is probable that the Philadelphia specimen, if it is really *microbrachius*, is to be accounted for in a similar way. — The range of this species seems to be along the coast of Central America and Mexico between the parallels 8° and 27° N. lat., thus nearly coinciding with that of *kubiniji*, but extending somewhat further south.

Remarks. — This species is so easily recognized, when adult, that its standing can scarcely be questioned, yet the young are often quite perplexing, for even when 70–80 mm. in diameter, they may have the rays quite long and slender, and free 30–35 per cent of their length. The small, slender, and numerous abactinal spines, however, make even these young ones recognizable. There are usually 35 or 36 rays, and I have seen only one specimen with more than 40, though curiously enough that one has 44. There are only two specimens before me with less than 30 rays, and of these the one with 27 is not quite full-grown, as R is less than 60 mm.

Material examined: —

32 specimens.	Acapulco, Mexico.	M. C. Z. collection.
1 specimen.	Lequina Bay, L. C.	" "
1 "	Mazatlan, Mexico.	" "
1 "	" Panama, Pacific side."	" "
1 "	"Pacific Coast of Mexico."	" "
1 "	"Chili."	" "
1 "	La Paz, L. C.	U. S. N. M. "
2 specimens.	" West Coast Central America or Mexico."	" "
40 specimens.	8 localities.	

Heliaster cumingii (Gray).

Plate 5, Fig. 1.

Asterias Cumingii Gray, 1840.
Asterias solaris Carpenter, 1856. ?
Heliaster Cumingii Dujardin and Hupé, 1862.
Asterias Cummingii Lütken, 1872.
Heliaster cumingi Clark, 1902.

Description. — Rays 32–40, averaging (34 adults) 35.6; about 23 (15–30) per cent of ray free. R = 55–90 mm.; r = 40–73 mm. Breadth of ray at base, 7–12 mm.

R = 7–8 br. Rays more or less flattened, both actinally and abactinally, tapering abruptly to a blunt point so that the free portion is nearly triangular; the length of the triangle is a little greater than the breadth, while the distance between the tips of any two rays about equals the breadth of a ray. Disc very large, somewhat elevated at the centre but very gradually. Abactinal skeleton very stout with small meshes. Whole abactinal surface covered more or less uniformly, but not very thickly (15–20 per sq. cm.), with nearly cylindrical, rather stout spines, one to two millimeters long. These spines are not usually capitate, but in some specimens many of them are. On the margin of the disc and bases of the rays, the spines show some tendency to arrangement in radial series with three series to a ray, but when this arrangement is most evident, the spines in each series are noticeably few and those in the lateral series are very conspicuous. — Sides of ray with one or two series of compressed spines. — Actinal surface much as in *helianthus*, but the interbrachial areas are more extensive and have numerous papulae. Adambulacral and other spines more or less variable, not essentially or constantly different from those of *helianthus;* owing to the greater fusion of rays, and consequent increase of the interbrachial areas, the series of spines outside the adambulacral extend further inward. Buccal depression and membrane as in *helianthus.* Pedicellariae very small, both forficate and forcipate present, but the latter are more abundant and are most abundant on rays abactinally. The pedicellariae are infrequent, and often seem to be entirely wanting on the actinal surface. — Pedicels in a zigzag row on each side of the ambulacrum, so crowded near middle of ray as to be quite distinctly quadriserial there. — Madreporite as in *helianthus.* — Color of abactinal surface deep bluish-black; spines (at least at tip) light brown, yellow, yellowish, or whitish; actinal surface whitish or yellowish, with pedicels darker than spines and papulae; madreporite brownish or blackish.

Range. — Hood's Island (Gray); Chatham Island (U. S. N. M.); Abingdon Island (U. S. N. M.); Albemarle Island (M. C. Z.); Charles Island (M. C. Z.). — This species is confined to the Galapagos Archipelago, and apparently occurs throughout the group.

Remarks. — As the type of *cumingii* is lost, it would be impossible to decide to what form that name ought to be applied, were it not that the locality given by Gray, with his brief description, leaves no doubt that the short-rayed Heliaster of the Galapagos is the species he had before him. As Gray's description is so brief, it was very natural that Verrill (**1867**) should say of his Peruvian specimens that they "are, perhaps, the species described by Gray." When Peruvian and Galapagian specimens are laid side by side, however, the difference between them is usually very noticeable, and, as previously stated, I have felt justified in calling them by different names, for the following reasons: — (1) The differences between them are obvious and uniformly associated with locality. (2) These differences are quite constant, and connecting forms are wanting or very rare. (3) The geographical isolation of the Galapagian form is very complete, Heliaster being so exclusively littoral. (4) In no other way can the differentiation of the Galapagian Heliasters be so well emphasized. Nevertheless it is freely admitted that there is room for difference of opinion as to the wisdom of this course, for the probable existence of connecting links among Galapagian specimens would cause

some zoölogists to make use of a subspecific name, while others might not consider the differences sufficiently great and constant to warrant any attempt to distinguish the two forms by name. Although the large series of specimens before me, 101 in all, have made it possible to compare the two forms very carefully, the only apparent connecting links I have seen are from the Galapagos. None of the 53 Peruvian specimens show any intermediate characters or offer any difficulty in assigning them to the mainland form. Of the 48 Galapagian specimens, those (6) in the collection of the Leland Stanford Junior University are all unmistakably *cumingii*, and the same is true of five of those in the collection of the Museum of Comparative Zoölogy. There are two young ones, however, in the latter collection, one 44 mm. in diameter, the other about 80, which are less easily determined. The former is of course too young to show any specific characters clearly, while the larger one has the abactinal spines coarser and more nearly capitate than in most Galapagian specimens. However, as Rathbun (**1887**) has pointed out, the young quite commonly have more capitate spines than the adults. Of the 38 specimens of Heliaster, supposedly from the Galapagos Islands, sent me from the National Museum, two are evidently *multiradiatus* (as already mentioned) and 17 are typical *cumingii*, while four others are too young to show specific characters. Of the remainder, nine are evidently *cumingii*, but resemble the Peruvian species in the conspicuously capitate spines, especially along the margins of the rays. The other six specimens demand a special word for each.

1 and 2. Under No. 21947 are two specimens, one of which seems to be a young *helianthus* and has been referred to under that species. The other is similarly labelled from an unknown locality, but is much larger, 150 mm. in diameter. It is apparently *cumingii*, though the spines on the abactinal surface of the rays are decidedly capitate. It probably came from the Galapagos.

3. Under No. 15523 is a young individual, about 72 mm. in diameter, labelled "Heliaster cumingii Gray. Chatham Island, Galapagos. Dr. W. H. Jones, U. S. N." It seems to be correctly identified, but the rays are free for an unusual proportion (35 per cent) of their length, giving the specimen a peculiar appearance, somewhat like *helianthus*.

4. No. 15524 is a large specimen, about 145 mm. in diameter, labelled "Chatham Island, Galapagos," and bears a striking resemblance to *microbrachius*. It has been so well and fully described by Rathbun (**1887**) that no description need be given here. This individual represents the extreme development of the peculiar characters of *cumingii*, except that the abactinal spines are unusually numerous.

5 and 6. Under 21948 are two specimens, about 145 mm. in diameter, concerning which we have only the information that they were collected by the "Albatross" in 1888, "Loc. ?" One of them is very similar to the Peruvian form, as the abactinal spines are very numerous, while the other, although similar, is more like Galapagian specimens. If these individuals are from the Galapagos Islands, they are apparently connecting links with the mainland form.

The young of *cumingii* not only have the free portion of the rays relatively longer than in the adult, but the abactinal spines are lower, stouter, and more capitate. Specimens under 75 mm. in diameter do not show the specific char-

acters clearly, and cannot always be distinguished certainly from mainland Heliasters of the same size. So far as the material at hand is concerned, the specimens from the different islands of the archipelago are quite indistinguishable, with the single interesting exception of the specimen from Abingdon Island. This individual is not adult, but has 35 rays and is unusually well preserved. The rays are remarkably slender, much as they are in some very young specimens of *microbrachius*. When compared with a specimen of the same size from Charles Island, the peculiarities of this Abingdon Island individual are well brought out.

Locality of Specimen.	R.	Free portion of ray.	Per cent free.	Breadth of ray at base.	Breadth in R.	Breadth in free portion of ray.
Charles Island	46 mm.	10 mm.	22	6 mm.	7.7 times	1.6 times
Abingdon Island	44 "	11 "	25	4 "	11 "	2.7 "

Material examined: —

6 specimens.	Albemarle Island.		Leland Stanford Jr. Univ.	Collection.
25 "	"	"	U. S. N. M.	"
1 specimen.	"	"	M. C. Z.	"
1 "	Abingdon	"	U. S. N. M.	"
6 specimens.	Charles	"	M. C. Z.	"
6 "	Chatham	"	U. S. N. M.	"
?3 "	Loc.?		"	"
48 specimens	5 localities			

Heliaster polybrachius, sp. nov.

Plate 2, Fig. 2; Plate 7, Fig. 12; Plate 8, Fig. 8.

Heliaster Cumingii Verrill, 1867a, p. 291; 1867b, p. 33, line 10, 334 and 344.
Perrier, 1878, p. 11 and 99.
Leipoldt, 1895.

Description. — Rays 31–43, averaging (38 adults) 37.1; about 18 (14–23) per cent of ray, free. R = 55–90 mm.; r = 45–77 mm. Breadth of ray at base, 9–11 mm. R = 6–8 br. Rays much as in *cumingii*, but free portions stouter as a rule, with more convex sides and blunter tip. Disc as in *cumingii*, but abactinal spines much more numerous, especially on the region where disc and rays join, 25–50 per sq. cm. Marginal series of spines on rays very distinct, but not usually noticeably larger than other abactinal spines. All of the abactinal spines are commonly low, of nearly uniform height, and more or less distinctly capitate.[1] Actinal surface as in *cumingii*, but pedicellariae are commonly abundant among the adambulacral and adjoining spines. Pedicellariae all small, as in *cumingii*. Buccal depression, pedicels, and madreporite also as in *cumingii*. — Color of abac-

[1] Leipoldt (1895) refers to a specimen in which the abactinal spines were three millimeters high, but none of the specimens before me have any over two, and they are commonly about one millimeter high.

tinal surface dull greenish, blackish, or black, often variegated with yellowish blotches; sometimes the appearance is that of a yellowish background with a few small blackish blotches; spines and actinal surface yellowish; pedicels and madreporite brownish.

Range. — Zorritos, Peru (Verrill); Payta, Peru (M. C. Z.); Chili (M. C. Z.). — The distribution of this species seems to be curiously limited, for while it appears to be very common at Payta, Zorritos is the only other port from which it is recorded. Aside from the specimens from Payta, there is a single poor and old specimen in the Museum of Comparative Zoölogy labelled "Chili," but nothing further is known of its origin.

Remarks. — The differences between this species and the preceding may be briefly summarized as follows: — In *polybrachius* the rays are more numerous, averaging more than 37 as against 35.6 in *cumingii*, and the free portion is shorter, stouter, and more bluntly pointed; the abactinal spines are much more numerous (25–50 per sq. cm. where thickest), lower and more capitate, and pedicellariae are usually abundant on the actinal surface, while in *cumingii* they are often wanting; the color of *polybrachius* is often lighter than that of *cumingii*, and the Peruvian specimens are frequently variegated abactinally with yellowish. The most obvious of these differences are well brought out in the figures given on plate 2. Doubtless there is room for wide difference of opinion as to the significance of these differences, and whether they are important enough to entitle the Peruvian form to a separate name. There are three possible courses, any one of which we might follow: — (1) We might call the Peruvian specimens *cumingii*, and simply point out the features in which they differ from Galapagian specimens; (2) we might call them a subspecies of *cumingii*, and make use of a trinomial name for them; (3) we might regard them as a distinct species. I have already given (p. 52) the reasons which lead me to consider the third of these possible courses the best, but I am free to admit that *polybrachius* and *cumingii* are so closely related that were they both found on the same coast I should consider it unwise to attempt to separate them. It seems to me clear, however, that one is an offshoot of the other, and the facts already given under *cumingii* with reference to the variability of the island specimens seem to show that that species is the offshoot from *polybrachius*, as the geographical distribution of the two forms would lead us to expect. The offshoot, however, is the one which has borne a name for over sixty years, while the parent stock has remained nameless. In selecting a name for it *polybrachius* has been chosen because the average number of rays is greater than in any other species of Heliaster.

Material examined: —

51 specimens.	Payta, Peru.	M. C. Z. Collection.
1 specimen.	"Peru."	" "
1 "	"Chili."	" "
53 specimens.	3 localities.	

The Number of Rays and the Order of their Succession.

The large number of rays in Heliaster is one of the most interesting features of the genus, but owing to the scarcity of material almost nothing has been done in the way of investigating the amount of variability in this character or the order in which the successively new rays appear. In 1872, Lütken showed that there is no correlation between size and the number of the rays in Heliaster, after a certain size (about 100 mm. in diameter), which we may call that of maturity, is reached; that is to say, very small specimens have a relatively small number of rays and this number increases with increasing size, only until the animal is approximately mature, after which there may or may not be a continued addition of new rays. Having only 15 specimens (*H. helianthus*) for comparison and only one of those less than 75 mm. in diameter, Lütken did not attempt to discuss the original number or the sequence of the rays, but it is hard to understand how any one could examine his data and not see that the number of rays certainly does increase after larval life and even after the starfish is 50 mm. across. Rathbun (1887) in his report on Heliaster makes statements in regard to *cumingii* which indicate his belief that the rays increase in number with increasing age (see p. 441, line 8). In spite of these writers, however, Perrier, as late as 1893, states that Labidiaster is the only starfish in which additional rays develop after the larval period is passed and the adult form assumed. In 1895, Leipoldt referred to the presence of two young rays in a specimen of *H. cumingii* (=*polybrachius*), about 50 mm. in diameter, which had otherwise only 24 rays. In 1900, Ritter and Crocker showed conclusively that Pycnopodia begins its post-larval life with only six rays, and that the additional 14–18 rays are in process of appearance, normally in pairs, until well into adult life. There can no longer be any question therefore that starfishes with twenty or more rays begin their post-larval life with a much smaller number and continue to add new rays for an undetermined period. Consequently specimens of Heliaster with fewer than twenty rays are sure to be met with and if age and size are disregarded, we cannot assign on *à priori* grounds the minimum number which a starfish of this genus may show. The smallest specimen among the 346 examined measures only 20 mm. in diameter, and I can find no published record of any specimen nearly as small. It is a young individual of *kubiniji* (U. S. N. M. No. 21950) from Lower California and has 12 rays, eight well developed, three much smaller and a twelfth barely started. With it are two other specimens, 25 mm. in

diameter, with 13 and 14 rays respectively. Another specimen of the same species from Guaymas, Mexico (U. S. N. M. No. 21949) is also 25 mm. in diameter but has 15 rays. A larger one (110 mm.) from the same place (U. S. N. M. No. 21941) has only 17 rays, of which two are very small; but this specimen like the individual of *multiradiatus* referred to on p. 48, which, although 200 mm. in diameter, has only 16 rays, is almost certainly the victim of an unusual accident. A specimen of *kubiniji* 64 mm. in diameter, from Acapulco, Mexico, (M. C. Z., No. 1171), has only 18 rays. I have neither seen, nor found a record of, a specimen of any species with 19 rays. The largest specimen of *canopus*, 120 mm. in

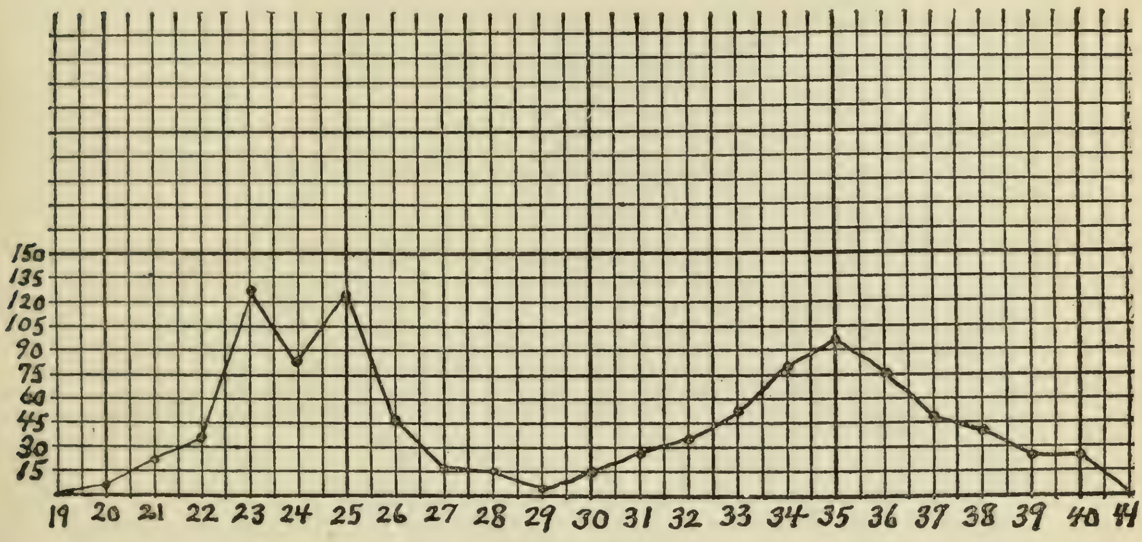


DIAGRAM 1[1].

To show the relative abundance (per thousand, regardless of species) of Heliasters with 20–40 rays. Based on 335 individuals.

diameter, and the smallest of *polybrachius*, 40 mm., have only 20 rays each. Above 20, all numbers occur up to 44, but I have seen no specimen with 41. There are eight specimens with 40 rays each (five of *polybrachius*, one of *cumingii*, one of *microbrachius*, one of *helianthus*); one *polybrachius* has 42, one *polybrachius* has 43, and one *microbrachius*, only 140 mm. in diameter, has 44. The number of specimens with from 20 to 40 rays inclusive is 335 and Diagram 1, based on this series, shows the number of individuals in a thousand having any given number of rays between 19 and 41.

A single glance at this diagram shows that there are two groups of Heliasters, one of which tends to have 23–25 rays, and the other 35, and

[1] In this and all the following diagrams: Horizontal lines show the number of individuals. Vertical lines show the number of rays.

that the two are almost completely separated from each other, since individuals with 29 rays are very rare. It is also clear that the group with fewer rays varies less from the normal number than does the other. It is worth while therefore to examine the species separately (omitting the obviously young) to bring out the difference in variability. As *cumingii* and *polybrachius* are so closely allied, they may be considered together, especially as there is no essential difference between them when tabulated separately. We will omit *multiradiatus* altogether as the number of available specimens is too few to make a reliable tabulation possible.

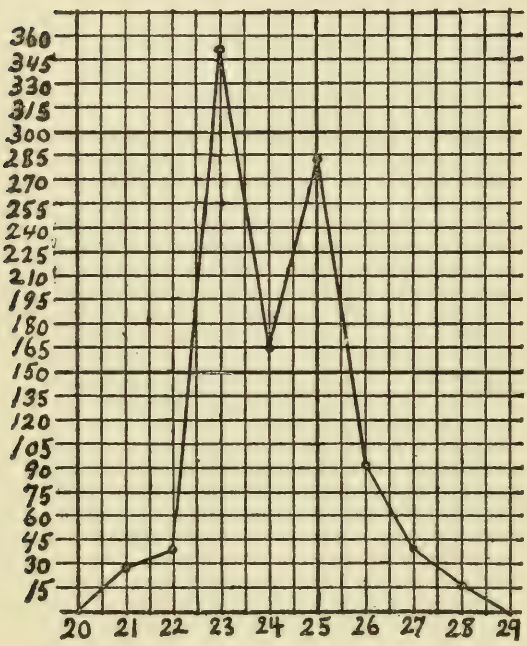


Diagram 2.

To show the relative abundance per thousand, of *H. kubiniji* with 21–28 rays. Based on 110 individuals.

The diversity in the number of rays in *kubiniji* is remarkably slight and is clearly shown in Diagram 2, from which it will be seen that practically 80 per cent have 23–25 rays and that nearly 69 per cent have an odd number. In *canopus* on the other hand (Diagram 3) only 48 per cent, have 23–25 rays, and only 37 per cent have an odd number. Although the small number of specimens available for comparison undoubtedly accounts in part for these peculiarities of *canopus*, it can hardly be doubted that this species shows a much greater tendency to variability in the number of rays than does *kubiniji*. In *helianthus* (Diagram 4) the number of rays varies from 30 to 40 but 64 per cent have 34–36 rays, while only 46 per cent have an odd number. In *cumingii* and *polybrachius* (Diagram 5) the number of rays ranges from 29–40 [1] and only about 36 per cent have 34–36, while almost exactly half have an odd number. The great variability of these two short-rayed species is especially notable in view of the fact that *microbrachius*, which is also short-rayed, agrees strikingly with *helianthus*, 63 per cent of the

[1] The two specimens of *polybrachius* with 42 and 43 rays respectively are omitted from the diagram.

specimens having 34–36 rays, and only 42 per cent have an odd number.

Turning now from the amount of variability to the method of formation of new rays and the order of their appearance, we are favored by the fact that in Heliaster the stomach is provided with five pairs of conspicuous muscles attached to the ambulacral plates of five of the rays, as in Asterias, and comparison of numerous specimens of all ages leaves no doubt that these five rays are, as one would naturally suppose, the original rays of the starfish on first assuming the adult form. This arrangement is strikingly different from that shown by Pycnopodia, where Ritter and Crocker (1900) found that the post-larval life apparently starts with six rays. The youngest available Heliaster (*kubiniji*), 20 mm. in diameter, has 12 rays but only eight of these are at all nearly equally developed and it is fair to assume that their arrangement represents the normal condition in an 8-rayed young Heliaster. Numbering the five original rays clockwise from the madreporite, as the specimen is looked at from above, we find there is an accessory ray between rays 1 and 2, 2 and 3, 3 and 4. (Plate 8, fig. 1). Adding now the four very young rays, in the positions where they occur, we find there are now three between 1 and 2, two between 2 and 3, two between 3 and 4, but there are still no rays between 4 and 5 or between 5 and 1 (Plate 8, fig. 2). In another young individual (*kubiniji*) with 15 rays, we have the condition shown in fig. 3 (Plate 8), where it may be seen that although there is now a ray between 4 and 5, 5 and 1 are still side by side. The youngest *polybrachius* has 20 rays, four of which are, however, very small; in this specimen there are three well-developed rays between 1 and 2 and also between 3 and 4, and 4 and 5, while there are only two between 2 and 3 and none between 5 and 1. On adding the four rudimentary rays, it is rather surprising to find that the conditions in the interradii 2 and 3 and 5 and 1 are not changed, but

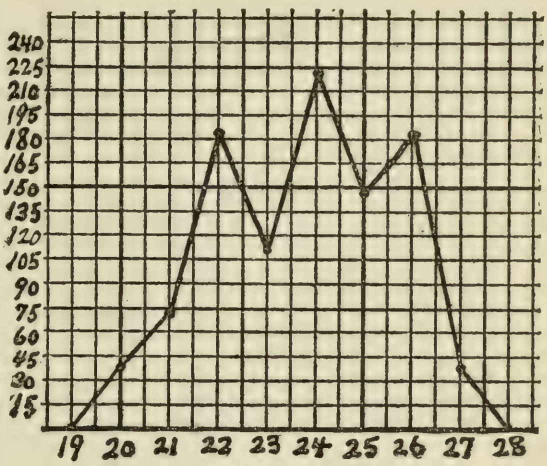


DIAGRAM 3.

To show the relative abundance per thousand, of *H. canopus* with 20–27 rays. Based on 27 individuals.

there are now five accessory rays between 4 and 5, and four in each of the interradii 1–2 and 3–4. The specimen of *canopus* with 20 rays differs only in that there are three rays in interradius 2–3, and only four in 4–5. An example of *kubiniji* with 21 rays gives the condition shown in figure 4 (Plate 8), but specimens of *canopus* with 21 rays are quite unlike this; one has six rays in 1–2, three in 2–3, four in 3–4, three in 4–5, and none in 5–1, and the other has four, three, five, four, and none, in the same order. Very similar to the latter is another *canopus* with 22 rays arranged 4, 4, 5, 4, 0. Specimens of *kubiniji* with 23 and 25 rays show the sequence given in figures 5 and 6 (Plate 8). The order 5, 5, 5, 3, 0, seems to be the normal arrangement for specimens of *kubiniji* with 23 rays, but in a specimen of *canopus*, the order is 5, 3, 5, 5, 0. With 24 rays the order in *kubiniji* is 5, 5, 5, 4, 0, while in an example of *canopus* it is 5, 3, 5, 6, 0. With 25 rays, *canopus* and *polybrachius* both agree with *kubiniji* in the symmetrical 5, 5, 5, 5, 0, and as this was found to be true of all of the six Heliasters having 25 rays, which were examined, it is fair to consider it the normal arrangement. In examples of *canopus* and *kubiniji* with 26 rays each, the additional ray occurs in interradius 1–2. In examples of the same species having 27 rays interesting conditions, undoubtedly abnormal, were found; in *canopus* (Plate 8, fig. 7) there are two rays in interradius 5–1, the only case, among 30 Heliasters examined, in which there are accessory rays in that interradius; in *kubiniji*, the stomach-muscle of 1 is missing, so that there are only four such muscles and the sequence of the rays is 9, 4, 6, 3, 0, with, of course, possible errors in the 9 and 0. After the number of rays gets beyond 26, there appears to be no uniformity in the order or position of the accessory rays, as is clearly shown by the following table: —

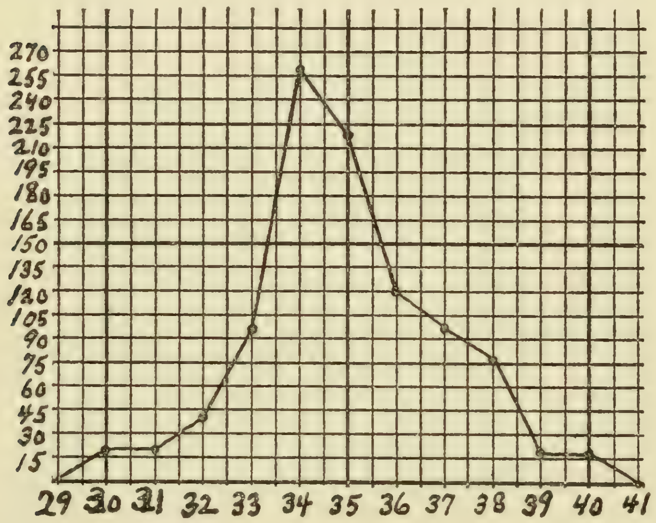


DIAGRAM 4.

To show the relative abundance per thousand, of *H. helianthus* with 30–40 rays. Based on 50 individuals.

Species.	Number of Rays.	Sequence in the Five Interradii.
canopus	27	6, 5, 5, 4, 2. (Plate 8, Fig. 7.)
kubiniji	27	9, 4, 6, 3, 0.
polybrachius	27	5, 5, 7, 5, 0.
microbrachius	31	8, 6, 7, 5, 0.
polybrachius	31	7, 5, 8, 6, 0.
helianthus	33	8, 5, 7, 8, 0.
helianthus	34	8, 7, 7, 7, 0.
helianthus	35	8, 7, 7, 8, 0.
microbrachius	35	8, 8, 7, 7, 0.
polybrachius	35	8, 7, 8, 7, 0.
polybrachius	37	8, 7, 9, 8, 0. (Plate 8, Fig. 8.)

The first indication of a new ray in Heliaster, which can be seen without a microscope, is an internal one, simply the gradual separation of the two halves of an interbrachial wall, close to the discobrachial wall.

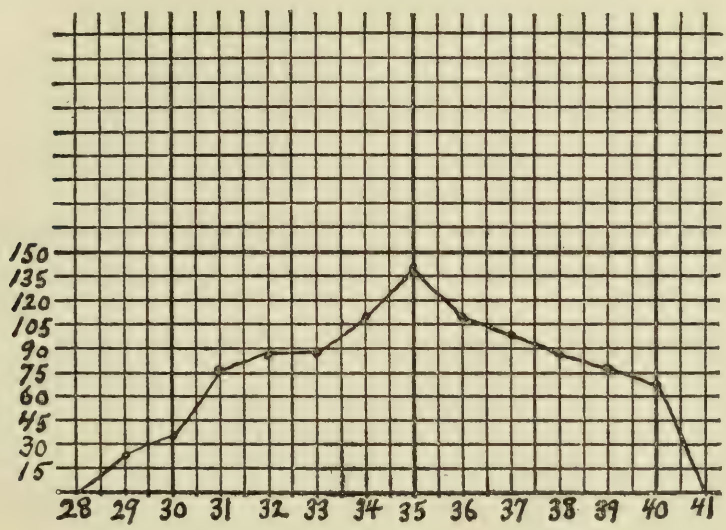


Diagram 5.

To show the relative abundance per thousand, of *H. cumingii* and *H. polybrachius* with 29–40 rays. Based on 88 individuals.

There can be little reason to doubt that the actual first step in the new ray formation is the pushing out of a bud from the outer side of the circumoral, watervascular canal, and the growth of this bud with its attendant tissues is the cause of the separation of the halves of the interbrachial wall; the bud itself becoming the radial water vessel. There is no direct evidence in support of this hypothesis, but it is reasonable, in line with the indirect evidence and open to no serious objection. After

the splitting of the interbrachial wall begins, it goes on more rapidly, if development is normal, towards the actinal surface, and the interbrachial tissues there soon separate and the pedicels of the new ray appear. The growth of the new ray forces the older rays on either side further and further apart until they are entirely separated, and the accessory ray takes its normal place between them. The growth of the new ray in length is more rapid than its increase in diameter, so that it is relatively more slender than the older rays. In many cases, owing to some obstacle, probably an unusually firm calcification of the interbrachial wall, the new ray fails to split that wall actinally and so is forced to grow upward and appear on the abactinal surface. Its subsequent growth may force the walls apart and it then settles down into its proper place and becomes a normal ray. Often, however, the interbrachial wall fails to yield and consequently the new ray is unable to develop, but remains as a rudiment on the abactinal surface, usually near the boundary between the true disc and the bases of the rays. Such rudimentary abactinal rays are by no means rare and may attain quite a size, although usually very small. The largest that I have seen is on a specimen of *cumingii* (U. S. N. M. No. 15523) 170 mm. in diameter; it is 23 mm. long and seven in diameter, with the base about 30 mm. from the centre of the abactinal surface of the disc; it is also remarkable in that the tip is turned in towards the disc, as though one side had grown very much more than the other. Usually such an abactinal ray is situated between two normal rays, but not very rarely it is directly over a normal ray. Two explanations of this position suggest themselves; the aborted ray may have been forced into its present position by the growth of one of the normal rays, or a later bud has developed a normal ray where the aborted ray failed. — A comparison of the above given description of ray formation in Heliaster with Perrier's (1891) account of the same process in Labidiaster reveals such similarity as to leave no doubt that the process is identical in the two genera. It may be added that Perrier's figures could be duplicated from specimens of Heliaster, were it necessary, excepting only those showing regeneration. Cases of regeneration occur in Heliaster, but are not very common. Occasionally the tip of a ray is regenerated after loss, but several specimens show broken and healed rays where no regeneration is visible. Several cases occur of apparent regeneration of a group of rays, as though a large part of one side of the Heliaster had been cut (or bitten) off and the new rays were to replace those so lost; thus in one specimen of *microbrachius*, there are 24 normal rays and 13 much smaller, obviously young rays, side by

side; and in another specimen of the same species there are 25 normal rays and ten young ones side by side.

We are now in position to answer the questions raised by Ritter and Crocker (1900) concerning ray multiplication in Labidiaster and to compare the process in that genus and Heliaster with what takes place in Pycnopodia. The questions may be taken up in the order in which they were asked.

(1.) *Do the new rays come in in distinct generations?* They do not, but develop entirely independently of each other. A considerable number may develop at approximately the same time, often as many as six or seven and sometimes eight or nine in *H. polybrachius*, but they show no definite relation to each other.

(2). *Do the successive rays arise at the same and definite places?* There is much evidence to show that they tend to arise in all four quadrants of the circumference of the starfish about equally, but successively rather than simultaneously. This order is by no means consistently adhered to, however.

(3). *With what number of rays does adult life begin?* In Heliaster there can be little question that the number is five. There is no evidence yet known in the case of Labidiaster.

(4). *Are the new rays disposed bilaterally?* Not as a rule; this point is discussed more fully below.

(5). *Is there a ray corresponding to ray A of Pycnopodia?* Apparently not.

The symmetry of Heliaster, referred to under question four, requires a few words of description. Perfect radial symmetry is of course out of the question, as there is only one stone-canal and madreporite, but leaving those organs and the racemose and rectal glands out of account, approximate radial symmetry is possible in Heliaster, apparently only in the 5-rayed stage; for the interradius, 5–1 rarely develops any accessory rays and never as many as the other interradii. Bilateral symmetry, however, if we except the racemose and rectal glands, is clearly shown by some individuals, but the plane of division is quite different from that which Ritter and Crocker (1900) show is the adult plane in Pycnopodia. For while in Pycnopodia, the madreporite lies always in the second interradius to the left of the posterior half of the line of division, in Heliaster the only possible plane of symmetry is through the madreporite. In Pycnopodia moreover the plane is determined by the position of the accessory rays and every normal individual is bilaterally symmetrical (approximately of course), while in Heliaster the accessory rays have no

definite relation to the plane and only certain, relatively few, individuals reveal the symmetry. Theoretically, of course, any Heliaster with an odd number of rays show this bilaterality but in none of those examined was it shown, except those which had at least 25 rays. In all those with just 25 rays, the plane of symmetry, with 10 accessory rays on each side, is clearly indicated. Above 25, any odd number of rays may be accompanied by bilateral symmetry but it is not commonly, for of the 11 specimens tabulated on page 61, it will be seen that only one, a *helianthus* with 35 rays, can be considered truly symmetrical.

It appears therefore that in Heliaster, the formation of new rays is fundamentally different from that in Pycnopodia. This is well brought out by a comparison of figure 1, plate 8, with Ritter's and Crocker's (1900) figure 1, plate 13. In Heliaster the first three new rays are distributed one each in the three successive interradii to the left of the one in which the madreporite lies, while in Pycnopodia all three (counting A as the first accessory ray) lie in the single interradius 1–2. It is hard to believe that the two methods have anything in common, the ray A is so conspicuous and plays such an important part in Pycnopodia. In Heliaster the first accessory ray probably (?) appears in interradius 1–2, the second in 2–3, and the third in 3–4. Then apparently, as is shown by figure 2, plate 8, a new ray arises in 1–2, another in 2–3, another in 3–4, and then another in 1–2. Later on the process begins in interradius 4–5 and by the time 25 rays are formed, it is going on at about an equal rate in those four interradii. As we have already seen, it is only very exceptionally that the interradius 5–1 takes part in ray formation. It is not unfair to interpret the facts here brought out as showing that the formation of new rays in Heliaster follows this rule : —

The process begins in interradius 1–2, *soon after larval life ends, and goes on rapidly there until two or three accessory rays are formed, the similar activity of interradii* 2–3, 3–4, *and* 4–5 *following in order. At the time the process begins in* 4–5, *the rate of development in* 1–2 *has begun to decrease, and by the time there are* 25 *rays, each of the four interradii has formed five accessory rays, and the rate of development has greatly decreased and become approximately equal in them all. Subsequent formation of new rays follows the same general order, the twenty-sixth ray appearing in interradius* 1–2, *but after* 35 *rays are formed further development is sporadic.*

Of course it is not claimed for a moment that the above statement is a "law" governing ray formation in all Heliasters, as the material examined has been too scanty to determine how generally any such rule is

followed. But it can hardly be questioned that it indicates the usual course and is a natural deduction from the facts already given. The process is almost certainly continually modified by physiological conditions, one of which, at least, after the individual is well grown, is very possibly the amount and rate of calcification in the different interradii. Such unknown factors often cause some striking deviations from the suggested rule, as in the two cases previously mentioned, a *canopus* with 24 rays, where interradius 2–3 has only three accessory rays, while 4–5 has six, and a *polybrachius* with 20 rays, where interradius 2–3 has only two accessory rays and 4–5 has five.

If the above suggested rule is the usual course, we should expect to find that in specimens with from 21 to 30 rays, those with an odd number would predominate, but that in those with from 31–40 rays, there would be less tendency to an odd number, and the chances of odd or even would have been about equal. And such proves to be the case; for of 163 mature specimens having 21–30 rays, 98 or 60 per cent have an odd number, while of 170 specimens with 31–40 rays 86, or almost exactly half, have an even number. It is interesting in this connection to call attention to the fact mentioned on p. 45, that *canopus* has a marked tendency to an even number of rays, although they range from 20 to 27. If *canopus* is omitted, there are 89 out of 136 specimens with 21–30 rays, or 66 per cent which have an odd number. The condition in *canopus* is difficult to account for but it is apparently associated with a peculiar tendency in interradius 2–3 to fall behind in the production of new rays. In all of the six specimens examined with from 20–24 rays, that interradius has a smaller number of rays than 3–4, and in four of the six, it has the smallest number of any of the four interradii. In none of the ten specimens of *canopus* examined does interradius 2–3 have a larger number of rays than 3–4. The cause for this curious condition is obscure and we need make no attempt here to determine it, but it seems clear that it accounts for the tendency to an even number of rays in *canopus*. It may be added that there is no very obvious reason why interradius 5–1 develops no accessory rays, although it is very probable that the presence of the stone-canal and axial organ in that interradius is associated with the cause.

In the light of all the facts here brought out with reference to ray formation in Heliaster, it is, to say the least, unfortunate that Ritter and Crocker (1900) should have said (p. 263): — "The inconstancy and irregularity of the phenomena of new ray formation certainly finds no support in what takes place in *Pycnopodia* and, as we have shown,

the process will probably be found to be perfectly definite in *Heliaster* also."

The Relationships of Heliaster.

So obvious are the resemblances between Heliaster and Asterias, that such students of starfishes as Müller and Troschel (1842) and Lütken (1872) declined to separate them generically and even Gray (1840 and 1866) only proposed Heliaster as a subgenus. Dujardin and Hupé (1862) and Perrier (1875), however, considered the multiradiate forms entitled to full generic rank, but very closely related to Asterias. Viguier (1878), on making a careful study of the skeleton, reached the conclusion that Heliaster is not only generically different from Asterias but that it actually is entitled to rank as a family, distinct from the Asteriidae, which he called the Heliasteridae. Since the publication of his paper, Viguier's opinion has been almost uniformly adopted and the Heliasteridae has been accepted as a natural family. The examination of the large amount of material accessible to me has led me to feel that the question needs to be reopened and the evidence re-examined.

Viguier gave six characters upon which the family Heliasteridae is based and we will consider them in the order in which he presents them.

1. *The large number of rays, even more than in Pycnopodia.* This is an obvious and useful characteristic, but as Labidiaster has full as many rays as those Heliasters which have the largest number; as Pycnopodia scarcely falls short of the Heliasters which have the smallest number; and as there is as great a difference between *H. polybrachius* and *H. kubiniji*, as there is between the latter and *Coscinasterias calamaria* (Gray), it does not seem as though much stress could be laid on this point.

2. *The extended coalescence of the rays.* This is also an obvious character but it is not wholly confined to this genus for in some Asterids such as *Asterias ochracea* Brandt (Plate 6, fig. 3) the fusion of the rays is quite as great as in some Heliasters. Thus a specimen of *A. ochracea* with R = 100 mm. has only 71 mm. free which is practically the same proportion as in some specimens of *H. multiradiatus.* Clearly this character is not altogether distinctive.

3. *The separation of the rays by very strong, true interbrachial walls.* This is probably the best character of which Viguier speaks, for such starfishes with numerous rays as Labidiaster and Pycnopodia, have no true interbrachial walls. It should be pointed out however that the

beginnings of just such walls as occur in Heliaster are to be seen in *Coscinasterias calamaria* (Gray) (Plate 6, fig. 2) and they are well developed in *Asterias ochracea* Brandt (Plate 6, fig. 3). Consequently too much importance must not be attached to this feature.

4. *The position of the mouth at the bottom of a sort of funnel.* The value of this character is an open question but there is no reason for supposing it has any great significance as a structural feature. It is nearly or quite wanting in many individuals, although the best preserved specimens show it more or less clearly. Even if it were always present in normal living individuals, it could hardly be considered of sufficient importance to be a family character.

5. *The fragmentation of the madreporite.* Although the madreporite of an adult *H. helianthus* is usually fragmented, and although the same is true of the other forms with more than 30 rays, yet in young specimens of these species and in adults of *kubiniji* and *multiradiatus* such is not the case, but the madreporite is, on the contrary, exactly as it is in Asterias, simple and convex. The condition of the madreporite cannot then be used even as a generic character.

6. *The peculiar and remarkable form of the odontophore.* In regard to this point, there is room for difference of opinion, for while no one questions the interesting fact which Viguier emphasizes that the basal interbrachial plate (or "odontophore" as he calls it) is fused in Heliaster with a larger interbrachial plate behind it, it is difficult to determine how much value such a character has from a taxonomic point of view. Sladen (1889) holds that it has little or no value and that greater differences in this plate may occur between closely allied species than between other species of quite different genera, so much depends on the number of rays and the character of the adambulacral plates. Careful comparative study of the actinal skeleton of Asterias and Heliaster leads me to believe that Sladen is quite right and that we cannot place any exceptional weight on peculiarities in this so-called "odontophore."

The characteristic features of the family Heliasteridae, then, as given by Viguier, do not seem to bear close examination, and fail to prove of sufficient constancy and distinctiveness to warrant the separation of the genus Heliaster from the Asteriidae. Before the matter is considered settled, however, there are other points to be examined which will throw some light on the subject. It is remarkable that Viguier fails to mention the conspicuous discobrachial wall of Heliaster (Plate 6, fig. 1), for there is no other feature of the anatomy which is so characteristic of the genus. It is quite possible that, with the small amount of material

at his disposal, he did not feel justified in mutilating a specimen to such an extent as to expose this wall sufficiently to make him realize its unique character. It shuts the cavity of each ray off from the cavity of the disc completely, the only communication between the two being a small foramen through which the duct of the digestive gland passes. I have found no trace of any such wall in any other starfish which I have examined, and, although further investigation may show that it is not unique, it is undoubtedly the most striking feature of the internal anatomy of Heliaster. It is easy, however, to see how such a wall might have developed, for, with the coalescence of the rays and the consequent doubling of the interbrachial walls, it would be natural that a stronger union between the rays and disc should arise by the expansion of the proximal ends of those walls. The subsequent increase and coalescence of such expansions would readily follow, thus giving a very unusual, but necessary, strength to what would otherwise be a line of weakness. — The further examination of the internal anatomy of Heliaster reveals some interesting similarities with Asterias, which have not been noted hitherto. The reproductive organs occupy the same position as in that genus, and are identical in form, so that the only difference is in the actual number of gonads, there being a pair in each ray in both genera. The form and position of the stone-canal and the axial organ are identical in the two. The racemose glands (Tiedemann's bodies) are similar in form and position, but are much more numerous in Heliaster than in Asterias, ranging from 10 to 26 in the twelve specimens of *kubiniji* and *polybrachius* examined. They do not show any regularity in position, however, or any correlation between their number and the size of the individual, or the number of rays. The digestive system of Heliaster (Plate 7, fig. 1) is surprisingly like that of Asterias in spite of the separation of the disc cavity from the rays. The stomach is very capacious, and is obviously pushed out of the mouth in feeding, just as in Asterias, and (as already mentioned on p. 59) its five pouches are each attached by a pair of strong muscles, as in that genus, to the ambulacral plates of the basal part of a ray. These muscles pass from the stomach through the openings in the discobrachial wall (which are perhaps a trifle larger in these rays) used by the ducts of the digestive glands. This pentamerous symmetry of the stomach-muscles is most striking, and it can hardly be doubted that it reveals a close relationship to Asterias. The intestine is short, and bears the customary rectal gland, which consists, as in Asterias, of several much divided branches.

Turning now to the external features of Heliaster, we find, as is well known, that the abactinal skeleton, the papulae, the pedicellariae, and the armature of the adambulacral plates are essentially the same as in Asterias. It has commonly been stated also that the two genera are alike in the quadriserial arrangement of the pedicels. As a matter of fact, however, the real arrangement of the pedicels in Heliaster is quite different from what is found in Asterias, for while a quadriserial arrangement does occur in some species of Heliaster, it is virtually confined to the middle portion of the ray, while in other species it is hardly correct to speak of a quadriserial arrangement at all. These various conditions are shown on Plate 7 from which it will be seen that although in the middle of the ray there is a distinctly quadriserial arrangement in *microbrachius* (Fig. 11), in *kubiniji* (Fig. 9) that is scarcely the case. At the base of the ray the arrangement is unqualifiedly biserial in all the species (Fig. 10), at least for the first ten or twelve pairs of pedicels. In young individuals (Fig 12), the biserial arrangement is marked even at the middle of the ray. This condition is certainly perplexing if Heliaster is merely an Asterias with numerous rays, for if that were the case, the species with the fewest rays (*kubiniji*) ought to show most clearly the quadriserial arrangement, while a young individual with only 17 rays certainly ought to have the same arrangement well marked. As we have just seen, the reverse is the case. However, it seems probable that increase in the number of rays, in a species having four rows of pedicels, with the consequent lateral crowding, would lead to radial extension, which would result in the quadriserial arrangement gradually becoming irregularly, and finally perfectly, biserial, as we find it at the base of the rays in Heliaster. That such a result does follow an increase in the number of rays in a species with the quadriserial arrangement of the pedicels, is shown by *Coscinasterias calamaria* (Gray) (Fig. 13), where the first two or three pairs of pedicels of each ray are arranged in a single series on each side. If, however, we are to assume that the change here first indicated in Coscinasterias is continued in Heliaster to a far greater extent, we shall have to admit that it is carried to different degrees of completeness in the different species. It seems to have gone further in the species with the narrower, freer, and more cylindrical rays, where the quadriserial arrangement is nearly obliterated, than in those with broader and flatter rays, where the pedicels still appear to be in four series at the middle of the ray. Apparently, after there are 15–20 rays, the change to a biserial arrangement of the pedicels is not promoted so much by the number or degree of coalescence of the rays, as by their form and width.

From this brief summary of the more obvious anatomical features of Heliaster it is clear that the relationship with Asterias is very close, the only important differences being in the number of rays, the degree of their coalescence and the resulting modification of the actinal skeleton and arrangement of pedicels. It will of course be a matter of opinion whether these differences warrant the maintenance of the family Heliasteridae. It seems as though such a course emphasized too strongly the differences between Asterias and Heliaster and tended to conceal their much more important resemblances, and while the Heliasters might be considered a sub-family (Heliasterinae) of the Asteriidae, it would be unwise to isolate them further. If this sub-family be recognized, it is possible that the two Heliasters with relatively few, long, free rays (*multiradiatus* and *kubiniji*) could be separated generically from the others. It is difficult to do this, however, on account of the intermediate characters shown by *canopus*, which has few, rather long, and quite free rays, but whose natural relationship is obviously with *helianthus.* Should we make a second genus of these two species, leaving *cumingii, polybrachius,* and *microbrachius* for a third, we should doubtless have a natural grouping of the species, but the definition of these "genera" would tax the keenest specialist, and it is difficult to see any real advantage from such a division. It is, moreover, quite possible that when these starfishes are studied as living organisms (instead of as museum specimens), and from a more extensive series of localities, our idea of their interrelationships may be considerably changed.

Granting, then, that Heliaster is to be accepted as a genus of Asteriidae, we may well inquire as to its relation to other genera of that family, and we naturally turn to Pycnopodia as a probable near-ally, on account of the large number of rays. That Heliaster is allied to Pycnopodia has recently been both assumed and affirmed by Ritter and Crocker (**1900**). They make the following statement in a footnote on page 249 : — "There appears to be general agreement among authorities that *Pycnopodia* and *Heliaster* are rather more closely related than are *Heliaster* and *Labidiaster.* A. Agassiz, **'77**; Perrier, **'93**; Ludwig, **'97**; Studer, **'84**; Vignier, **'78**, etc." (both in this place and on p. 270, Viguier's name is misspelled, by a common typographical substitution). As my own investigations had led me to a different conclusion, I looked up the references here given, making use of course of Ritter's and Crocker's bibliography, with the following remarkable result: —

A. Agassiz, '77.

North American Starfishes. Mem. M. C. Z., **5**, No. 1.

No mention is made of either Heliaster or Labidiaster, nor can I find the slightest hint of the writer's opinion on the position of either genus. I may add further that Mr. Agassiz assures me that he has never expressed or held any such opinion as is here ascribed to him.

Perrier, '93.

Traitê de Zoologie. Première partie. Paris, 1893.

The author makes no direct reference to the question, but the position he assigns to Heliaster might not unfairly be interpreted as showing that he holds the view ascribed to him.

Ludwig, '97.

Die Seesterne des Mittelmeeres.

I have been able to find no reference whatever to any one of the three genera concerned, though I have very carefully and repeatedly examined this splendid monograph.

Studer, '84.

Abh. d. k. Akad. d. Wiss. zu Berlin, p. 1–64.

No reference whatever is made to either Heliaster or Pycnopodia.

Viguier, '78.

Arch. de Zool. exp. et gen., **7**, p. 33–250.

Although the author does not make any positive statement as to the relationship of Pycnopodia and Heliaster, it is clear from his remarks on page 116 that he does not consider them closely allied, while the statements on pages 118–119 indicate that he does consider Heliaster as intermediate between the Asteriidae and Brisingidae (to which family Labidiaster is commonly assigned), while Labidiaster, he thinks, may be intermediate between Heliaster and Brisinga.

It is clear, therefore, that the only "general agreement" which these five authors show is in avoiding the expression of any such opinion as is ascribed to them. It is very difficult to understand why Ritter and Crocker should have given these references at all, for they certainly do not support their contention, even indirectly.

On comparing specimens of the three genera concerned it will be seen that superficially they are somewhat similar, but that the more numerous rays and the larger disc ally Labidiaster and Heliaster more closely to each other than to Pycnopodia, although the stout abactinal skeleton of Heliaster separates it from both. The ambulacra in Pycnopodia are moreover very broad, and the pedicels are distinctly quadriserial almost to the actinostome, while in Heliaster the ambulacra are nar-

rower and the pedicels distinctly biserial at the base of the ray, as they are in Labidiaster throughout; the general appearance of the ambulacra in Heliaster is thus more like Labidiaster than it is like Pycnopodia. The buccal membrane and the mouth parts are essentially alike in all three genera, while the adambulacral armature shows no close similarity between either two. The pedicellariae are alike in all three, but those of Heliaster (Plate 7, figs. 2–5), while somewhat more like those of Pycnopodia in form, are distributed more as in Labidiaster. The digestive system of the latter is more like that of Pycnopodia than it is like that of Heliaster; at least the material available to me shows no indication of the five pairs of stomach-muscles, so characteristic of Asterias and of Heliaster, in either Pycnopodia or Labidiaster, nor can I find any reference to them in the published descriptions of either genus. In the number of racemose glands, Heliaster and Labidiaster are alike, having a large number (usually more than 15, often more than 20) without definite arrangement, while Pycnopodia, according to Ritter and Crocker, has only 9 or 10, and these are definitely located. The discobrachial wall of Heliaster is wanting in both the other genera, and even their interbrachial walls are reduced to mere sheets of connective tissue with little or no calcification. Were the case to rest here we should still be somewhat in doubt as to whether Heliaster or Pycnopodia were the nearer to Labidiaster, but there could be little question that Heliaster is nearer to the latter than it is to Pycnopodia. There is, however, another and very important point to be considered, and that is the location and sequence of new rays, which, as we have already seen, is apparently alike in Heliaster and Labidiaster, and places them in striking contrast to Pycnopodia. This feature alone is sufficient to completely separate the last from the others, and Viguier's opinion that Heliaster is intermediate between Asterias and Labidiaster seems therefore to be justified by these more recently discovered facts. Whether the latter is intermediate between Heliaster and the Brisingidae is somewhat less certain. The geographical connection between Heliaster and Labidiaster is obvious, since the latter replaces the former on the southern coasts of South America, but the remainder of the Brisingidae are, for the most part, widely separated geographically from Labidiaster, and there is reason to believe that they have originated from the Asteriidae quite independently of that genus. On the whole, it looks as though Labidiaster had originated as an offshoot from Heliaster, living in colder and deeper water, while Odinia, and perhaps Brisinga, too, are probably similarly related to the genus Asterias.

The Interrelationships of the Species, and the Factors which have aided their Development.

There are few starfishes whose habitat is so exclusively littoral as that of Heliaster, and there are not many genera, containing several species, whose area of distribution is so circumscribed. For these reasons the genus offers an unusual opportunity for the study of the influence of environment and the effect of isolation. Although this study could only be properly carried on in the regions where the Heliasters live, nevertheless the examination of a large number of specimens suggests certain conclusions which are worth noting. In the first place we see there are four areas, which so far as our present knowledge goes, are distinctly separated from each other, where Heliaster occurs, namely:— West Coast of Mexico and Central America; West Coast of South America from Ecuador to Chili, inclusive; Galapagos Islands; Juan Fernandez. In each of the first three regions two species of Heliaster occur, and in the fourth, one, but there is no species common to any two of the districts. We have no means of knowing which species is nearest the ancestral form, but it seems almost certain that the species with the fewest and least united rays are the most primitive. We are equally ignorant as to the place of origin of Heliaster, but there can hardly be any question that it was somewhere along the mainland coast. If these two points are assumed, *kubiniji* must be the nearest to the original Heliaster. We can see that as there are no nearly allied species on the western tropical coasts of America to compete with it, this form might gradually spread southward, while it would not be likely to extend north of Lower California, as it would then come into competition with numerous other Asteriidæ. Whether Heliasters still occur on the coast of Colombia we do not know, but whether they do or not is of no special importance in this connection, for *kubiniji* does not range very far south of Mexico and is therefore entirely isolated at present from its South American relatives. These latter under the different environmental conditions south of the equator seem to have developed a larger number of rays and to have them more fully united, as we find in *helianthus*. By a continued (though slight) increase in the number of rays, and a marked increase in their coalescence, accompanied by the development of stouter, capitate, abactinal spines, *polybrachius* has arisen. The origin of *microbrachius* is less clear, but its affinities with *polybrachius* are so much more apparent than any with *kubiniji*, we are almost forced to believe that it represents a return northward of short-rayed Heliasters, which owing to

their obvious differences have not been in real competition with *kubiniji*, and which in the environment north of the equator, new to them, have developed the numerous, slender abactinal spines which distinguish them from their southern ally. The fact that *microbrachius* occurs at Panama and Pearl Island may be interpreted to support this hypothesis. The relationships of the island forms are obvious, for *multiradiatus* is very closely allied to *kubiniji*, *cumingii* is quite as close to *polybrachius* and *canopus* is almost certainly an offshoot from *helianthus*. — These relationships, both phylogenetic and geographical, may be indicated by such a sketch as Diagram 6, it being understood that the relative length of the lines has no significance whatever.

Because of the extremely littoral habits of Heliaster, there can be no question that the island forms have reached their present homes as larvae transported by ocean currents. Owing to the distances however and the slow rate of travel, the chance of survival is very small, and it must be seldom indeed that young Heliasters from the mainland ever reach the Galapagos or even Juan Fernandez. The latter islands seem to have been reached as yet only by the single species (*helianthus*) from the nearest mainland, which under the stress of new conditions has become changed so that it breeds earlier in life, and is consequently much smaller than its parent form, and has more delicate spines, and fewer, freer rays. The Galapagos have been reached by young *polybrachius* from South America and also by young *kubiniji* from Mexico, but if we may judge by the relative amount of change, Juan Fernandez was populated by Heliaster long before the Galapagos. At the latter islands, *cumingii* appears to be much more abundant than *multiradiatus*, so we are justified in thinking *polybrachius* was the first comer, but both are so recent, the changes are as yet slight.

Of the factors which have led to this development of diverse forms of Heliaster, one at least stands out so clearly that there can be little doubt of its importance, and that is *isolation*. Were only the mainland species known, this factor would not be so obvious, though it would be suggested by the apparent lack of Heliasters on the coast of Colombia. But when we consider the two Galapagos species, and particularly when we study *canopus*, it is hard to doubt that the complete isolation of these small groups of individuals has been of great importance in the formation of the new species. In the case of *canopus*, there has been sufficient time, so that the species is sharply distinct, while the Galapagos species seem to be as yet only imperfectly defined. It is not necessary to claim that isolation has been the only, or even the essential, factor. Indeed the

probable existence of connecting links between *cumingii* and *polybrachius* at the Galapagos makes it very unlikely that it is merely the environment and isolation which are at work there. It seems clear that natural selection has been an important agent in the case of *canopus* at any rate,

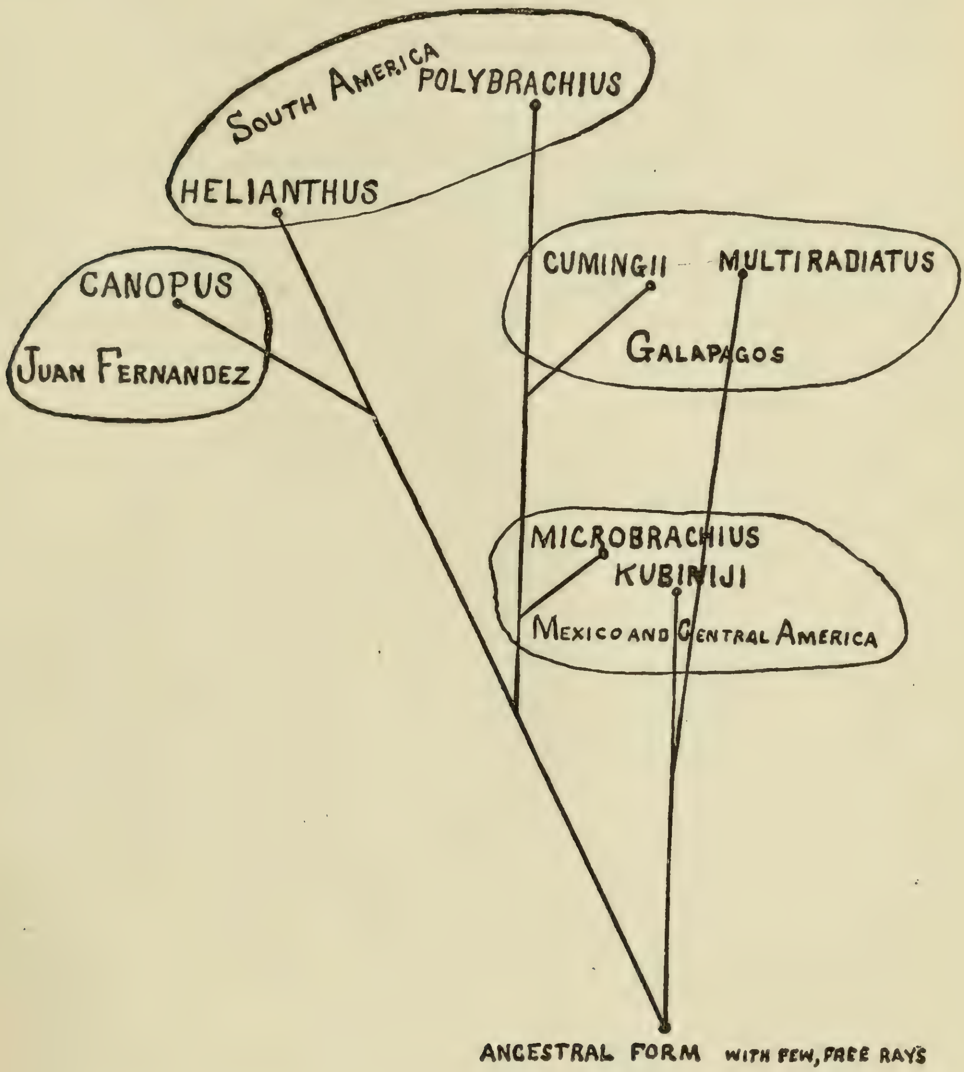


Diagram 6.

To show the phylogenetic and geographical relationships of the species of Heliaster.

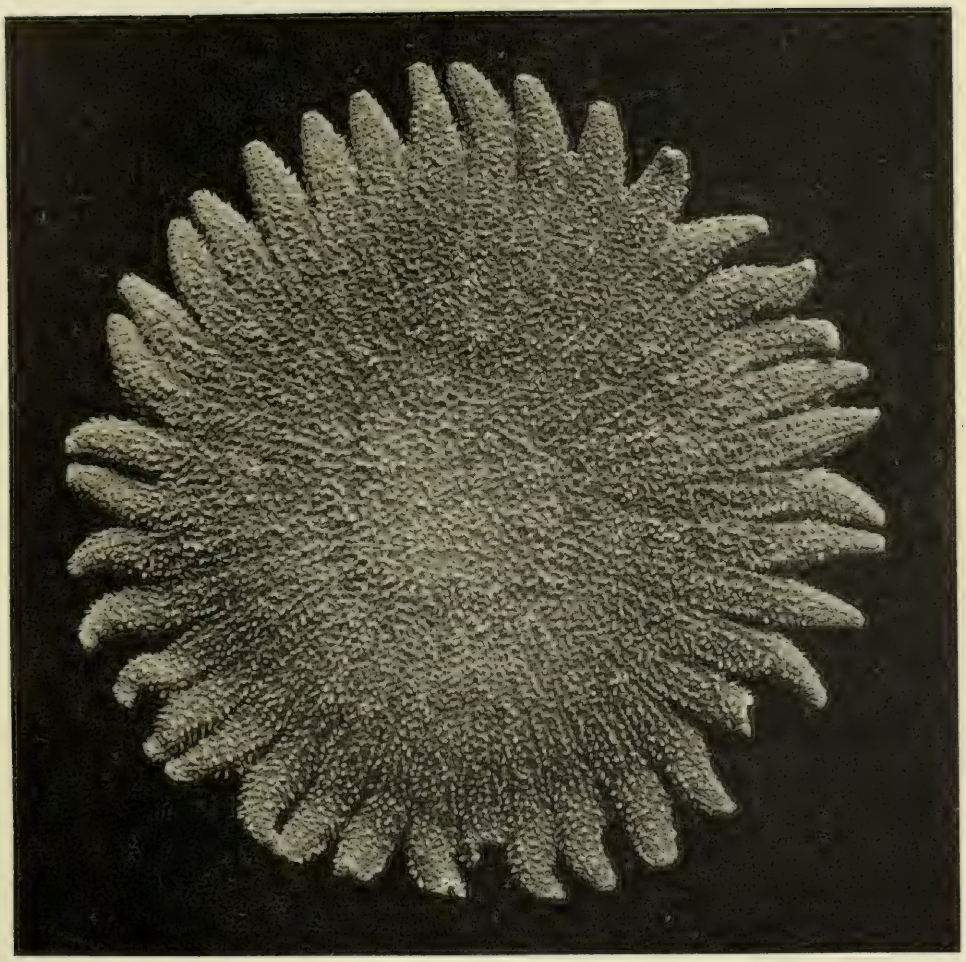
for while it can be claimed, if they please, by those, who are "done with meekly accepting the dictum . . . that when we understand *all* the conditions of the life of an organism, then and only then are we entitled to say of this or that character that it is not of life or death value,"[1]

[1] Kellogg, V. L., Science, Nov. 16, 1906, p. 627.

that the number of rays, the amount of their fusion, and the size and arrangement of the abactinal spines are characters of no value in the struggle for existence, there can hardly be any question that the ability to reproduce vigorous young, at an early period of life, would be a factor of importance in the establishment of Heliaster on an isolated island. As diminutive size, a small number of rays and their comparative freedom, and slender abactinal spines are youthful characters in Heliaster, it is significant that we find them correlated in *canopus* with sexual maturity. It can hardly be doubted that natural selection, aided by isolation and the correlation of characters, has, by working on an inherently variable and plastic organism, been the cause of the evolution of *canopus*, and I see no reason to question the probability that a similar process is going on in the formation of two new species of Heliaster at the Galapagos.

PLATE 1.

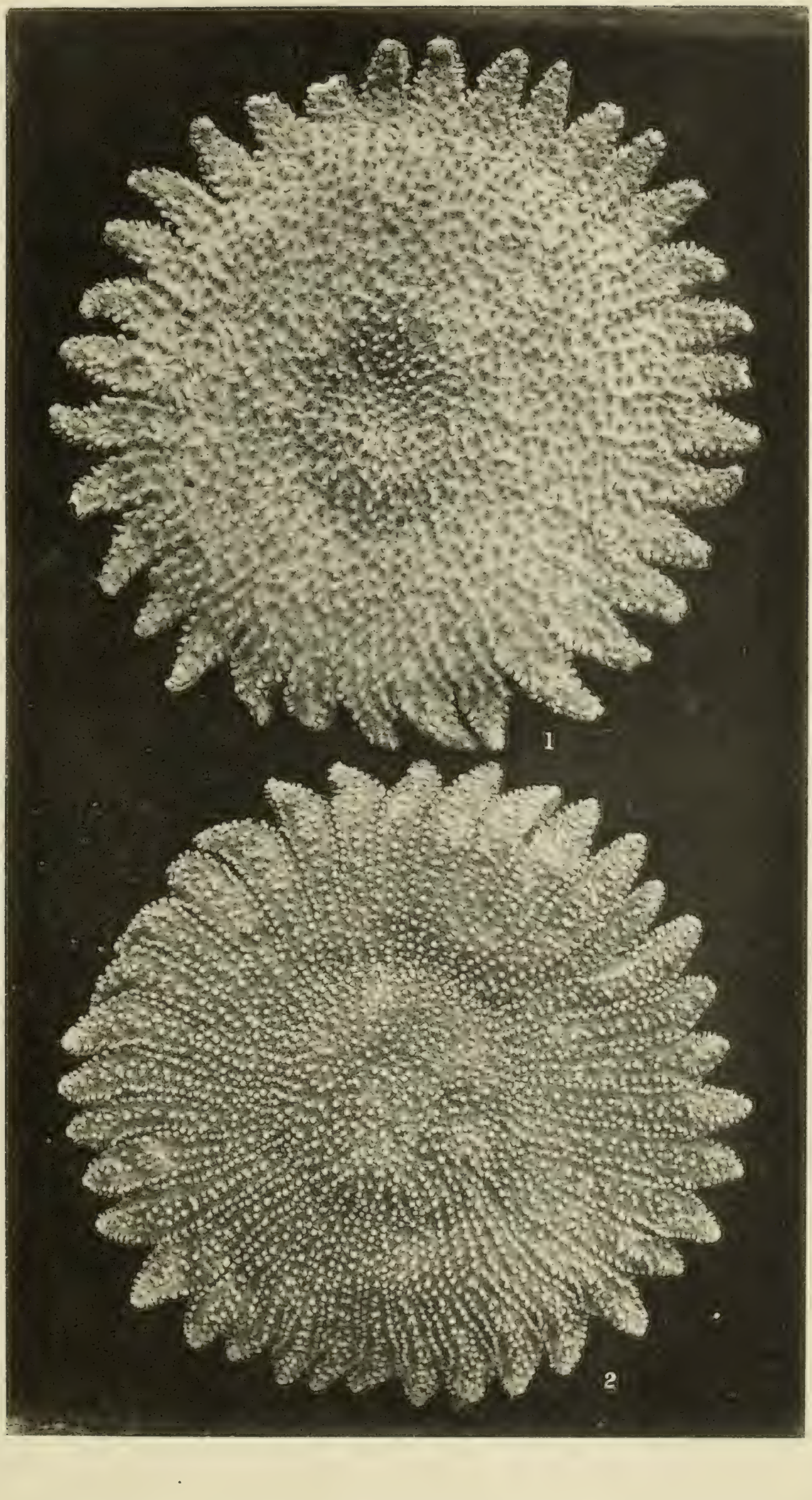
Heliaster microbrachius Xantus. Abactinal surface. $\times \frac{7}{10}$.



HELIOTYPE CO., BOSTON.

PLATE 2.

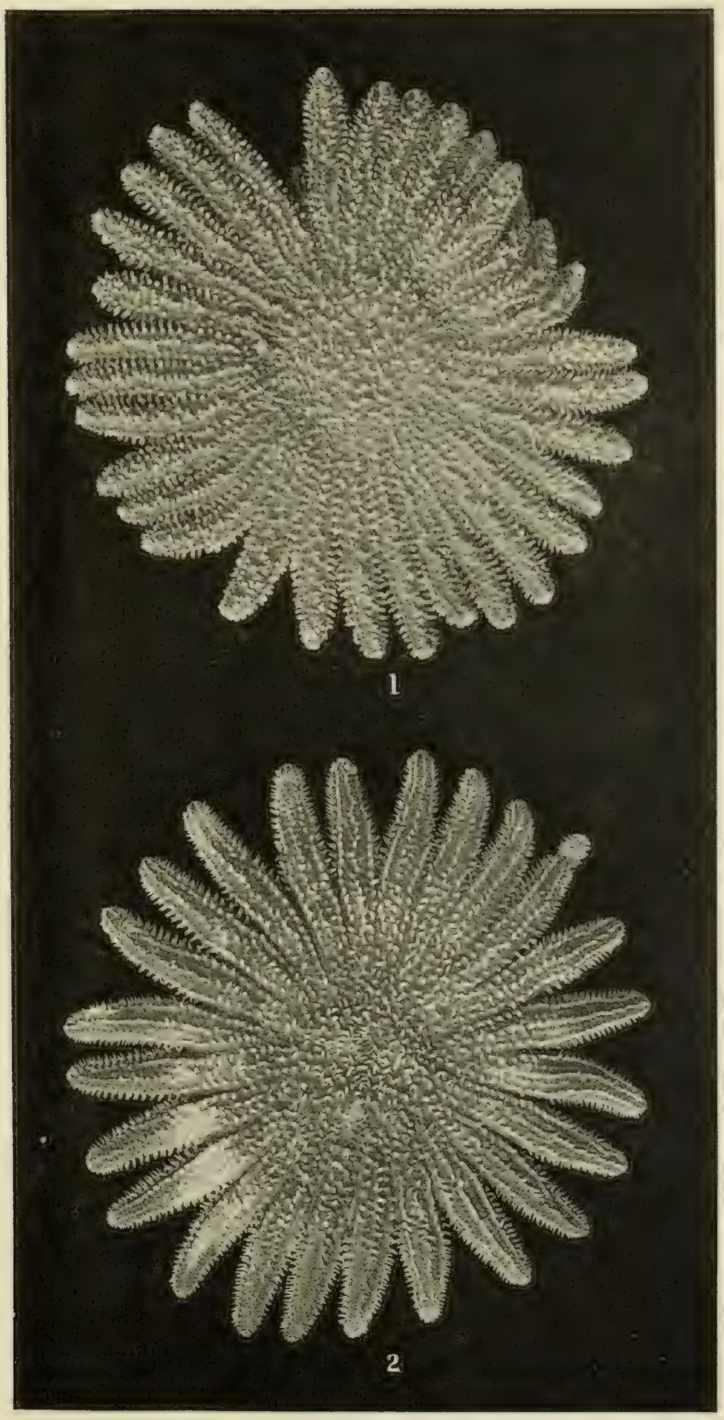
Fig. 1.	Heliaster cumingii (Gray).	Abactinal surface.		$\times \frac{7}{10}$.
Fig. 2.	„ polybrachius, sp. nov.	„	„	$\times \frac{7}{10}$.



HELIOTYPE CO., BOSTON.

PLATE 3.

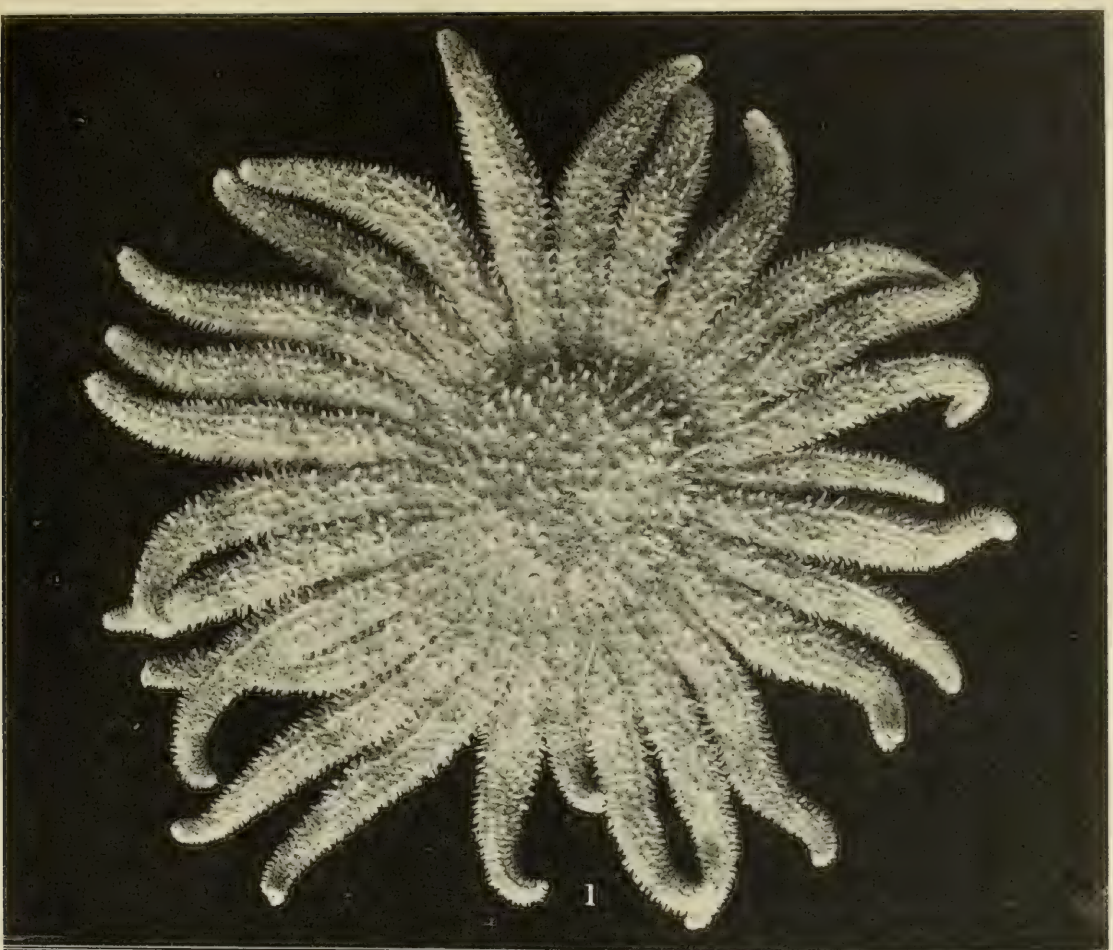
Fig. 1. Heliaster helianthus (Lamarck), juv. Abactinal surface. $\times \frac{7}{10}$.
Fig. 2. „ canopus Perrier, adult. „ „ $\times \frac{7}{10}$.

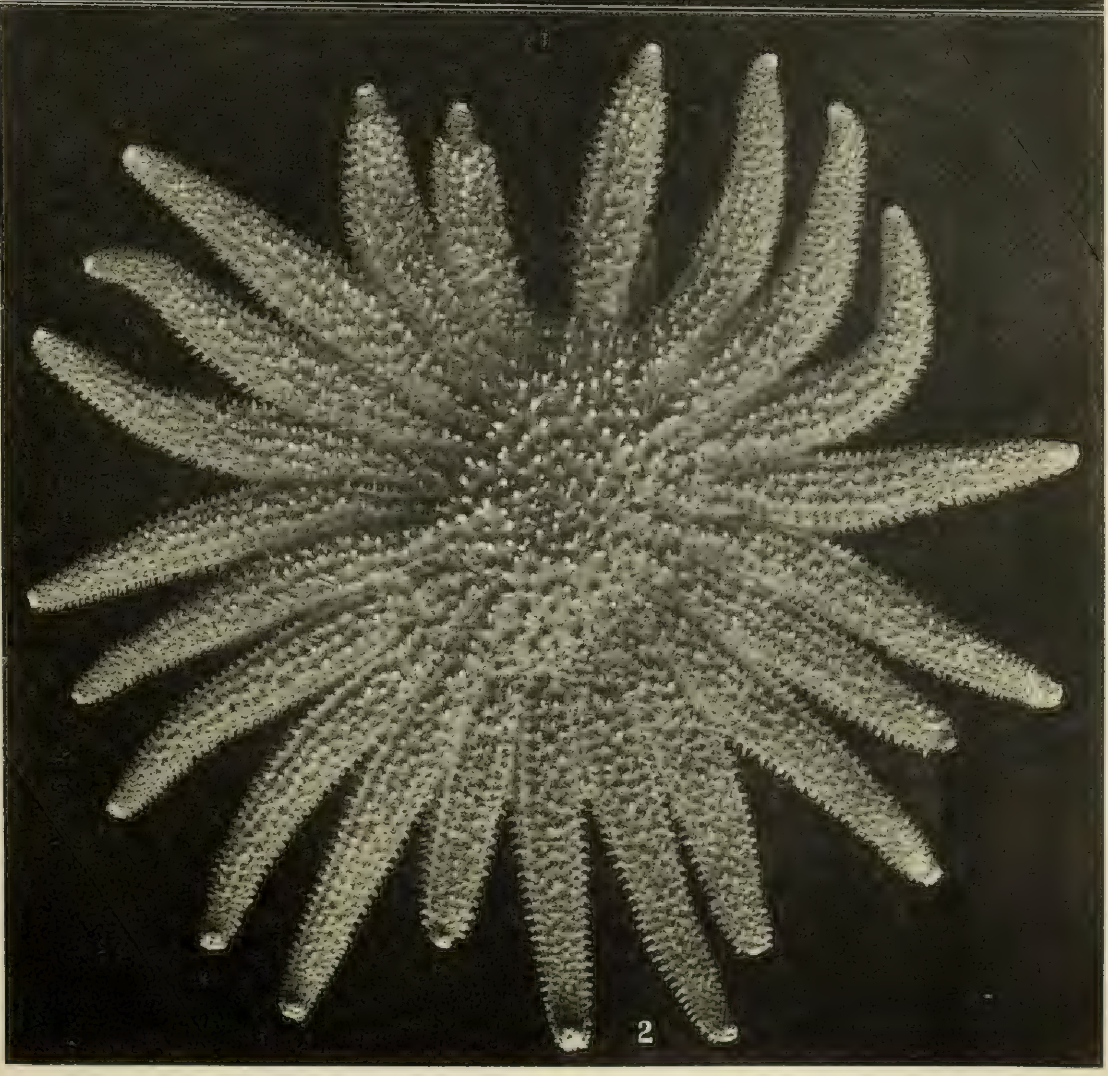


HELIOTYPE CO., BOSTON.

PLATE 4.

Fig. 1.	Heliaster multiradiatus (Gray).	Abactinal surface.	$\times \frac{7}{10}$.
Fig. 2.	„ kubiniji Xantus.	„ „	$\times \frac{7}{10}$.

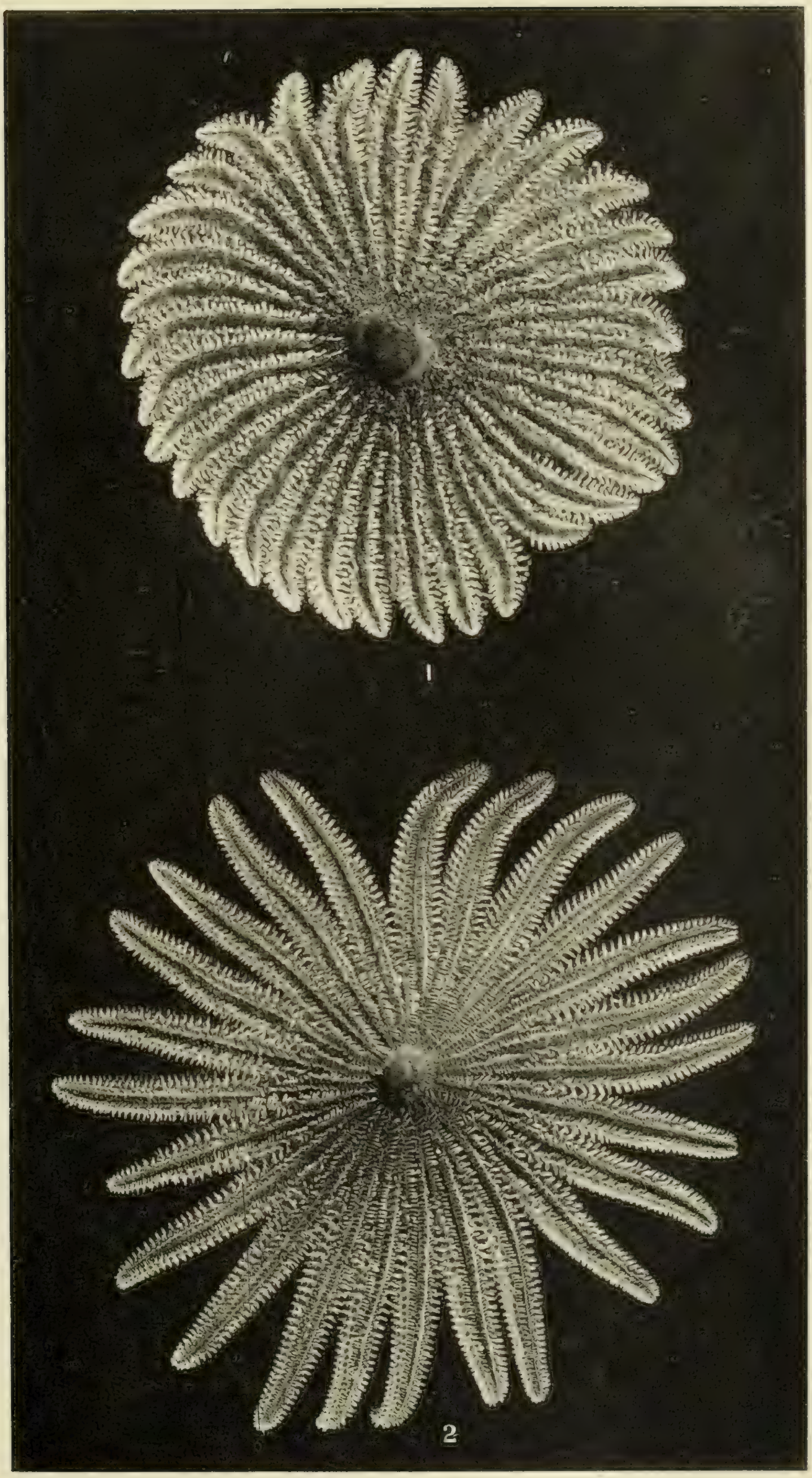




HELIOTYPE CO., BOSTON.

PLATE 5.

FIG. 1. Heliaster cumingii (Gray). Actinal surface. $\times \frac{7}{10}$.
FIG. 2. " " kubiniji Xantus. " " $\times \frac{7}{10}$.



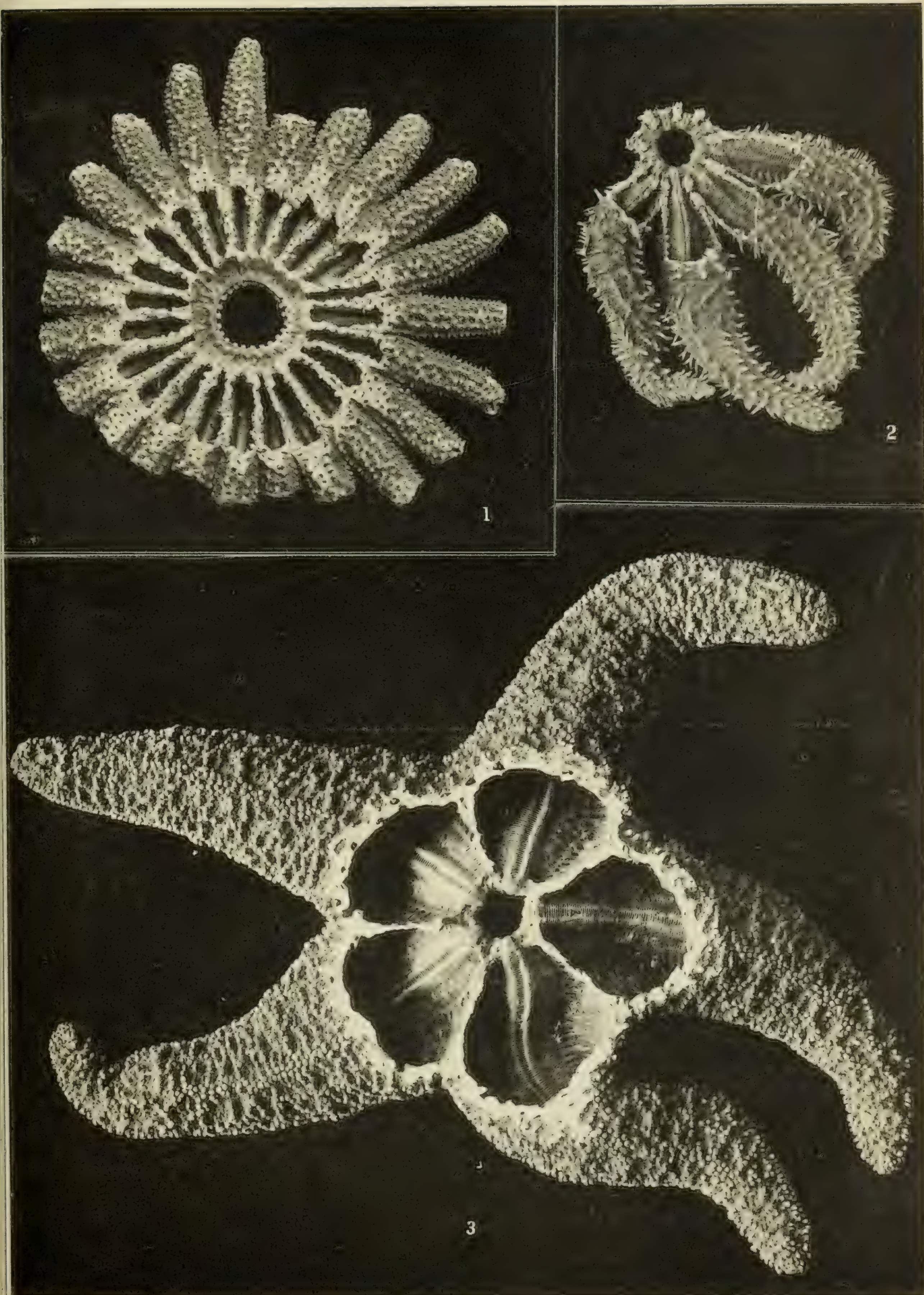
HELIOTYPE CO., BOSTON.

PLATE 6.

FIG. 1. Heliaster kubiniji Xantus. Abactinal surface and all inner organs removed, to show the interbrachial and discobrachial walls. $\times \frac{7}{10}$.

FIG. 2. Coscinasterias calamaria (Gray). Abactinal surface and all inner organs removed, to show the incipient interbrachial walls. $\times \frac{7}{10}$.

FIG. 3. Asterias ochracea Brandt. Abactinal surface and all inner organs removed, to show the coalescence of the rays and the interbrachial walls. $\times \frac{7}{10}$.



HELIOTYPE CO., BOSTON.

PLATE 7.

Figs. 1–7. Heliaster helianthus (Lamarck).

1. Digestive system, including the intestine (*IN*) with its rectal gland, the stomach with "blood-vessels" (?) (*BV*) on its abactinal surface, the bases of the digestive glands of three rays, the ducts of the other rays, and the paired stomach-muscles of the five primary rays. The stone-canal (*SC*) may be seen between rays I and V. Nat. size.
2. A large forficiform pedicellaria. × 70.
3. A small „ „ × 70.
4. A forcipiform pedicellaria, from one edge. × 70.
5. A similar „ „ „ side. × 70.
6. The madreporite of a large adult. × 2.
7. „ „ „ „ well-grown young individual, 95 mm. in diameter. × 2.

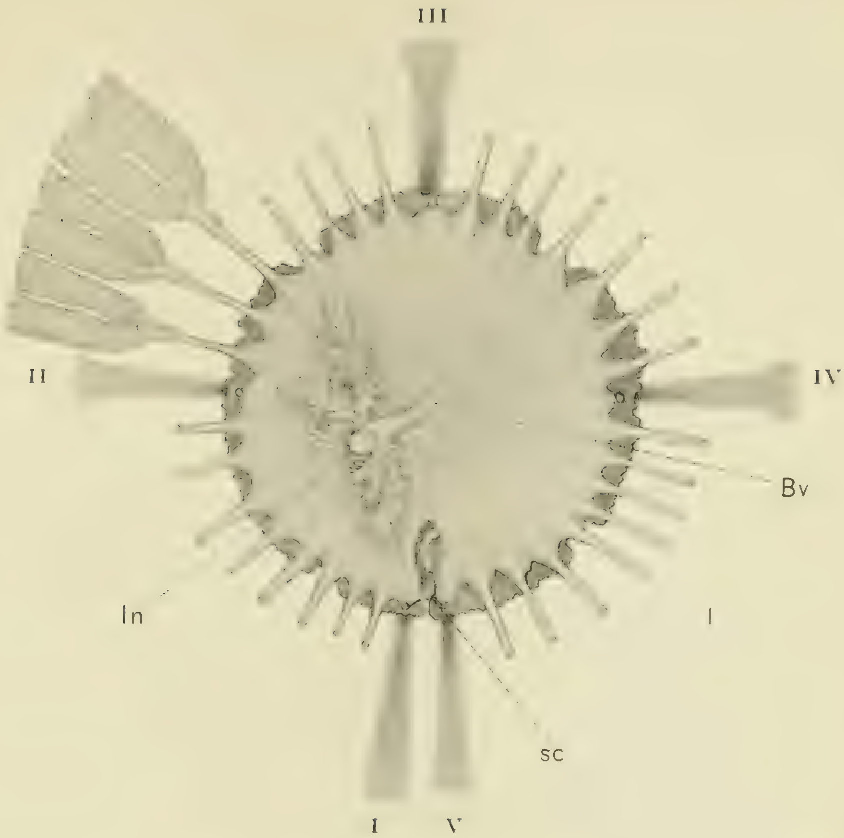
Figs. 8–10. Heliaster kubiniji Xantus.

8. The madreporite of an adult. × 2.
9. Ambulacral plates from near middle of ray, seen from the outside, to show the scarcely quadriserial arrangement of the pedicels. × 5.
10. Ambulacral plates from near peristome, seen from the outside, to show the biserial arrangement of the pedicels. × 5.

Fig. 11. Heliaster microbrachius Xantus. Ambulacral plates from near middle of ray, seen from the outside, to show the quadriserial arrangement of the pedicels. × 5.

Fig. 12. Heliaster polybrachius, sp. nov. Very young individual, only 40 mm. in diameter. Ambulacral plates from near middle of ray, seen from the outside, to show the biserial arrangement of the pedicels. × 5.

Fig. 13. Coscinasterias calamaria (Gray). Ambulacral plates from near peristome, seen from the outside, to show the biserial arrangement of the pedicels. × 5.

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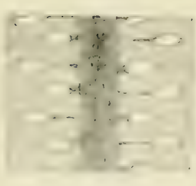
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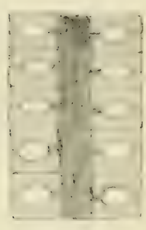
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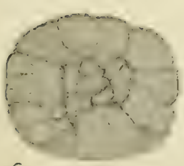
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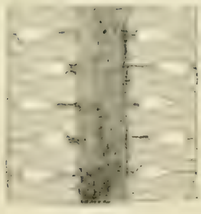
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HELIOTYPE CO., BOSTON.

PLATE 8.

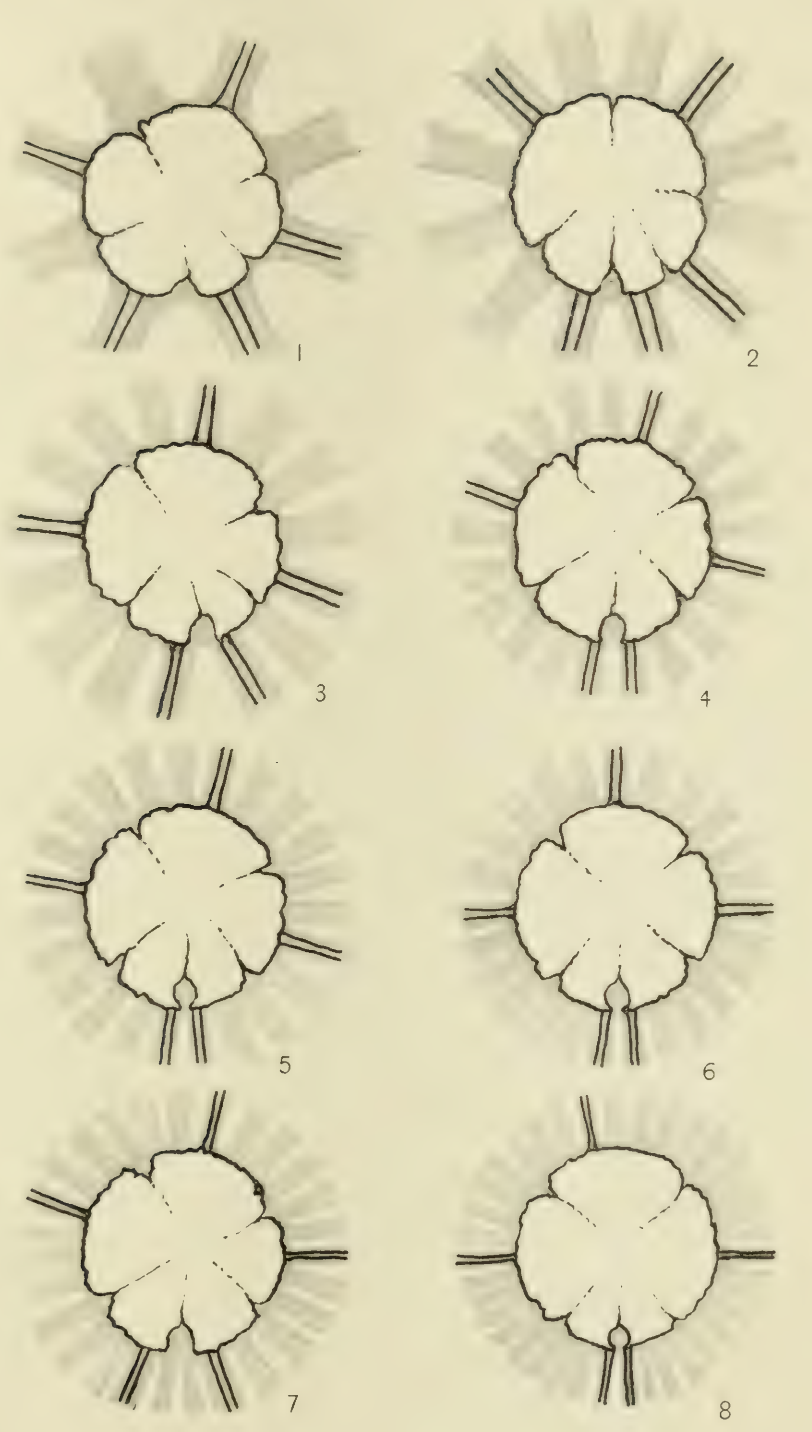
Diagrams to show the relative position of the five primary rays in Heliaster, and the increasingly numerous accessory rays. The heavy line indicates the outline of the stomach with its five pairs of muscles, which determine the primary rays.

FIGS. 1–6. Heliaster kubiniji Xantus.

1. An 8-rayed individual.
2. A 12-rayed „
3. A 15-rayed „
4. A 21-rayed „
5. A 23-rayed „
6. A 25-rayed „ (Note the remarkable symmetry at this stage).

FIG. 7. Heliaster canopus Perrier. An exceptional 27-rayed individual.

FIG. 8. Heliaster polybrachius, sp. nov. A large 37-rayed individual.



HELIOTYPE CO., BOSTON.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 3.

TYPES OF FOSSIL CETACEANS IN THE MUSEUM OF COMPARATIVE ZOÖLOGY.

By C. R. Eastman.

With Four Plates.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

June, 1907.

No. 3 — *Types of Fossil Cetaceans in the Museum of Comparative Zoölogy.* By C. R. Eastman.

There are preserved in the Museum of Comparative Zoölogy, besides other interesting Cetacean remains, the types and only known representatives of three species of Odontocetes from the middle and late Tertiary formations of this country. Two of these exemplars belong to the Delphinoid, and the other to the Ziphioid division of toothed whales. One of the Delphinoid types has served for the establishment of a distinct genus, Lophocetus, whose characters have been insufficiently described, and precise systematic relations are admitted to be uncertain. The original has never been satisfactorily figured, and its companion Delphinoid type, the so-called *Delphinus occiduus* of Leidy, has not been illustrated at all. The present Bulletin is devoted principally to a consideration of these two Delphinoids.

LOPHOCETUS Cope.

Proc. Acad. Nat. Sci. Phil., 1867, p. 146.

First described by Harlan in 1842 under the name of *Delphinus calvertensis*, the species was made by Cope the type of Lophocetus, and placed in the vicinity of Inia and Pontoporia (= Stenodelphis). In fact, it was held to be distinguished from the former of these genera only by the "cylindric form of the posterior alveolae, which renders it probable that the teeth were not furnished with lobes as in Inia." More than a score of years later, in 1890, the same author speaks with less assurance concerning its relations: "Its position is uncertain; the skull resembles that of Inia, but the roots of the teeth are cylindric. The temporal and occipital ridges are very strong. Skeleton unknown."[1]

Save for one or two exceptions, subsequent writers have accepted Cope's general determination. Dr. Theodore Gill, in 1872, recognized Inia and Platanista as types of independent families, and provisionally placed Lophocetus among fossil Iniidae.[2] The more usual practice has been to assign subfamily values to the groups represented by the two modern genera, and include them under Flower's comprehensive designation of Platanistids. Dr. O. P. Hay accordingly refers Lophocetus, though with some reservation, to the subfamily Platanistinae.[3] On the other hand Dr. E. C. Case states positively that its position is with the Iniinae

[1] The Cetacea. Amer. Nat., 1890, **24**, p. 606.

[2] Arrangement of the families of Mammals. Smithson. Misc. Coll., No. 247.

[3] Fossil Vertebrata of North America. Bull. 179, U. S. Geol. Surv., 1902, p. 590.

among "forms with cylindrically rooted teeth." [1] The only author who has argued against an association with Platanistids, as commonly understood, is Prof. J. F. Brandt, who concluded from the general aspect of the skull and form of the teeth that it approached very closely the existing Whitefish, *Delphinapterus leucas.* He even questioned the propriety of regarding it as the type of a distinct genus: "Der Schädel ähnelt offenbar dem von *Delphinapterus leucas.* Als Typus einer eigenen Gattung möchte ich sie daher, wenigstens vorläufig, noch nicht gelten lassen." [2] Within recent years Dr. Othenio Abel has reiterated the same opinion.[3] Thus the matter stands at the present time.

It may be well to present here Cope's original definition of the genus, to which nothing has since been added. This is given as follows:

LOPHOCETUS Cope.

"Temporal fossa truncated by a horizontal crest above, prolonged backwards and bounded by a projecting crest, which renders the occipital plane concave. The same crest prolonged upwards and thickened, each not meeting that of the opposite side, but continued on the inner margins of the maxillary bones, turning outwards and ceasing opposite the nares. Front, therefore, deeply grooved. Premaxillaries separated by a deep groove. Teeth with cylindric roots."

Lophocetus calvertensis (Harlan).

1842. *Delphinus calvertensis* Harlan, Bull. of Proc. Nat. Inst., p. 195, Plates, **1–3**.

1842. *Delphinus calvertensis* Dekay, Nat. Hist. N.Y. Zool. pt. 1, p. 136.

1842. *Delphinus calvertensis* Markoe, L'Institut, **10**, p. 384.

1866. *Pontoporia calvertensis* Cope, Proc. Acad. Nat. Sci. Phil., p. 297.

1867. *Lophocetus calvertensis* Cope, Proc. Acad. Nat. Sci. Phil., p. 144, 146.

1869. *Lophocetus calvertensis* Leidy, Journ. Acad. Nat. Sci. Phil., (2) **7**, p. 435.

1873. *Lophocetus calvertensis* Brandt, Mém. Acad. Imp. Sci. St. Petersb., (7) **20**, p. 288.

1880. *Lophocetus calvertensis* Van Beneden and Gervais, Ostéographie des Cètacés, p. 512.

1890. *Lophocetus calvertensis* Cope, Amer. Nat., **24**, p. 606, 615.

1896. *Lophocetus calvertensis* Roger, Verzeichniss fossiler Säugethiere, p. 79.

1899. *Lophocetus calvertensis* Abel, Denkschr. k.k. Akad. Wissench., **68**, p. 869, 873.

1902. *Lophocetus calvertensis* Hay, Bull. 179, U. S. Geol. Surv., p. 590.

1904. *Lophocetus calvertensis* Case, Maryland Geol. Surv. Miocene, **26**, p. 9, Plates 16, Fig. 1.

The type specimen consists of a well-preserved skull, from which the lower jaw and forward extremity of the muzzle are wanting. There are preserved besides all of

[1] Maryland Geological Survey, Miocene, 1904, p. 9.

[2] Die fossilen und subfossilen Cetaceen Europa's. Mém. Acad. Imp. Sci. St. Petersb., (7) 1873, **20**, p. 288.

[3] Fossile Platanistiden des Wiener Beckens. Denkschr. k.k. Akad. Wissensch., 1900, **68**, p. 869.

the cervical vertebrae. The latter, with the exception of the atlas, which remains adherent to the occiput, are not mentioned in the original description nor in any subsequent notice of the specimen. On the other hand, the principal features of the skull are well signalized by both Harlan and Cope, from the former of whom we quote as follows: —

"This interesting fossil consists of the skull, nearly complete, densely petrified, very weighty, tinged of a deep black, ferruginous color; characteristic marine fossil shells adhere to its base. . . . The external border of the superior maxillary bones is slightly broken on each side. Its discovery is due to the active researches of Mr. Francis Markoe, Jr., Corresponding Secretary of the National Institution, who obtained it from the Calvert cliffs, on the right bank of the Chesapeake bay, State of Maryland, along with other characteristic fossils. . . .

"The present specimen belongs to Cuvier's first subgenus, or "*les Dauphins à long bec*" [= type of Champsodelphis Gervais]. On comparison with the numerous species of living dolphins, it is found distinct from all of them. It approximates the Delphinapterus leucorampus, of Peron,[1] but differs in its various measurements, number of teeth, and in the arrangement of the palatine bones. . . .

"*Description of D. Calvertensis.* — In general outline, resembling other skulls of this genus. The head is proportionally narrower, and snout more elongated, than the Italian specimen with which I have compared it. The occipital and temporal ridges are strongly developed, indicating muscular strength, especially of the jaws. We find similar indications in the remains of the teeth, which have been large and robust. There are ten sockets remaining on the right side, with the teeth broken off at the rim. These organs approximate each other. The ten sockets include a line four and a half inches long. There has been about one and a half inches of the end of the snout broken off, which would afford room for two or three more teeth, making twelve or thirteen in all, on each side. The pyramidal eminence anterior to the posterior nares, on the palatine surface, is strongly pronounced. It terminates opposite the last tooth. The excavations or longitudinal grooves, on each side of the upper portion of this eminence, are unusually deep. The palatine surface is slightly convex transversely. Above, the head is narrower across the occipital ridges than other allied species, and narrower than the transverse diameter of the base of the skull. The ossa nasi are longer than broad, and convex. The atlas vertebra adheres to the occiput, above the condyles. It measures, across the transverse processes, five inches; transverse diameter, three inches; and the ring is about one inch thick." — (p. 196).

In connection with the above description, the following measurements are given, to which we have added their metrical equivalents in parentheses. The author states in regard to the missing portion of the rostrum that "one and a half inches must be considered as the length of the last portion of the extremity of the snout."

Dimensions:

Total length of head, from the temporal crest to the presumed extremity of the jaw . . . . 17 in. (432 mm.)

[1] *Vide* Cuvier, Ossemens Fossiles, **5**, pt. 1, p. 289, Plate **21**, Figs. 5 and 6, ed. 1823.

From the anterior border of the spiracles to the presumed extremity of snout	11.5 in. (292 mm.)
Breadth of skull above, across the occipital crests	5.0 in. (127 mm.)
Breadth at base, between the temporal bones	6.5 in. (165 mm.)
Longest diameter of largest tooth at the socket	0.35 in. (8.9 mm.)

Besides the foregoing, we may point out the following important characters whose combined weight is considered sufficient to establish beyond doubt the Platanistid relations of the form in question. (1) The cervical vertebrae are all free, and each one is of considerable length for a Cetacean; (2) the general form of the skull resembles that of Inia and Pontoporia (= Stenodelphis), but is relatively narrower behind, and has steeper lateral and posterior walls; (3) the large and nearly vertical parietals are widely separated from each other by the upward crowding of the supraoccipital, which is also wedged in between the frontals at the summit: in this region the frontals are visible only as narrow bands, continuous with the tumid nasals in front, enclosing the interparietal between them, and being themselves almost entirely concealed behind by the overroofing laminae of the maxillary elements; (4) the temporal fossa is large, and would appear to have been open in front; that part of the squamosal supporting the zygomatic process is very massive, and the orbital portion of the maxillary and frontal is correspondingly thickened; (5) the pterygoids are displaced from contact with each other in the median line through intervention of the vomer, and do not enclose an involuted air-space open behind; they entirely surround the palatines as in Inia and Pontoporia, and may have had (though this cannot be determined definitely from the present condition of the specimen) an articulation with the squamosal behind; the basal portion of the rostrum is wide and transversely arched; and (6), the premaxillaries, of extremely dense structure, are separated by a deep longitudinal cleft, and are broadly expanded without being inflated on either side of the narial orifices.

From the review already given it appears that, with the exception of Brandt and Abel, authors are agreed in including Lophocetus among Platanistids, but hold different opinions concerning which of the two subfamilies, Platanistinae or Iniinae, it is more nearly related. With Cope, we are persuaded that there is much greater structural resemblance to Inia and Pontoporia than to Platanista, among recent forms. The highly characteristic maxillary crests of the susu are not present in Lophocetus, the pterygoids do not unite in the median line to form an arch which almost entirely conceals the palatines, the latter do not extend in advance of the pterygoids along the basal portions of the rostrum, and the supraoccipital joins the parietals along crests that rise vertically and then flare slightly outwards, instead of being concave inwardly, as in the susu. On the other hand, as compared with Inia, only unimportant differences are found. The walls of the brain cavity are less rotund, the crests, as connoted by the generic name, are more powerfully developed, the nasals are crowded backwards so as to override the frontals at the vertex, which latter is divided by a deep longitudinal cleft, and the premaxillaries are more widely separated. The occipital condyles are rela-

tively broader in the fossil form than in Inia, but otherwise the bones forming the basicranial axis are remarkably similar. It is to be regretted that injury to the specimen prevents comparison of the bones in the orbital region, the zygomatic arch, and characters of the dentition. One can merely affirm that the teeth were single-rooted, and probably of cylindrical form, that is, without the additional tubercle shown by the posteriorly situated teeth in Inia. In so far as these latter may be said to recall something of the primitive condition of molars, whereas Lophocetus is homodont, the dentition of the Miocene genus is more specialized. But here we must not lose sight of the fact that Lophocetus is adapted to a marine, and Inia to a fluviatile habitat. The utility of a homodont-polyodont dentition to marine Carnivores, and the successive stages by which this condition is attained among Cetaceans, have been clearly demonstrated by Dames and others.[1]

In seeking for the nearest fossil allies of Lophocetus, attention is naturally directed first toward those forms which are regarded as standing in the immediate vicinity of Inia, possibly even in ancestral relations to the modern genus. Now a number of Tertiary forms are known whose characters accord in the main with those of Inia, and hence are properly included within the same subfamily. It may be doubted whether any of them fulfil the requisites of a direct ancestor of existing Iniinae, since they combine in their organization both generalized Cetacean characters, and also some others that indicate the animals were too specialized to be the progenitors of Inia. Among these Tertiary forms that present close structural resemblances to the modern type may be mentioned Iniopsis, from the Caucasian Eocene, the skull of which is incompletely known; several Platanistid species which are grouped by Abel under the new generic titles "Acrodelphis" and "Cyrtodelphis," from the European Miocene; and also the South American form described by Mr. Lydekker as *Argyrocetus patagonicus*. We should expect to find no less intimate resemblances between these forms and Lophocetus, on bringing them together.

Before undertaking comparisons, however, a word or two is necessary to explain the status and synonymy of the new names employed by Abel to designate practically the same grouping of species as was formerly included under Gervais's titles Champsodelphis and Schizodelphis. Both of these generic titles were suppressed by the Viennese author[2] in his memoir of 1899, and the names Acrodelphis and Cyrtodelphis substituted for them on the basis of newly

[1] Dames, W., Ueber Zeuglodon aus Aegypten. Pal. Abhandl., 1894, **5**, p. 212. — Fraas, E., Neue Zeuglodonten aus dem unteren Mitteleocän vom Mokattam bei Cairo. Geol. und Palaeont. Abhandl., n. s., 1904, **6**, p. 199–220. See also, concerning origin of polyodont dentition among Squalodonts, Kükenthal, W., Vergleichendanatomische und entwickelungsgeschihtliche Untersuchungen an Walthieren. Denkschr. Med.-Nat. Gesellsch. Jena, 1893, **3**, p. 421. — Weber, M., Studien über Säugethiere. Jena, 1886, pt. 1, p. 194–195.

[2] Abel, O., Untersuchungen über die fossilen Platanistiden des Wiener Beckens. Denkschr. k.k. Akad. Wissensch., 1900, **68**, p. 840.

defined differential characters, but without sensibly altering their respective contents. Thus, the type species belonging to the two older genera became in each case the typical species of the newly proposed genera. In other words, a valid generic distinction was recognized between two groups of fossil species for each of which a definite type was selected; and in each case the definite type so selected was identical with the type of a previously described genus. By this process of emendation and redefinition, the integrity of the older generic terms was not, and, according to ordinary rules of nomenclature, could not have been impaired. The genus Champsodelphis Gervais, typified by *C. macrogenius* (Laurill.) (=*C. macrognathus* Brandt), and represented by a number of other species as well, might be restricted, enlarged or otherwise modified, even broken up into several genera; but in the latter case the name Champsodelphis must be retained to designate that section which contains the original type of the genus. Similarly, in the case of Schizodelphis, so long as the typical species *S. sulcatus* Gervais is not proved to belong to any previously described genus, the original generic title must be retained, and no new one can be substituted in place of it. Therefore it becomes necessary to regard Abel's proposed title of Cyrtodelphis, having *S. sulcatus* Gervais for its type, as a synonym pure and simple of the older Schizodelphis, which has the same type species. In the case of Chamsodelphis, Abel has himself rectified his error of 1899 by restoring this name to good and regular standing. He restricts it in his Brussels memoir of 1905 so as to include only the type species, and employs the name Acrodelphis[1] as a collective designation for the nine or ten other species formerly embraced under Champsodelphis.

Some confusion exists as to exactly what constitutes the type species of Champsodelphis. Trouessart, in the quinquennial supplement, 1905, to his "Catalogus Mammalium," correctly indicates *C. macrogenius* (Laurill.) as the type. Abel, in his memoir published the same year, gives it as *C. macrognathus* Brandt. Both names refer to precisely the same thing. The extent of Brandt's changes was merely to restrict the application of Laurillard's title to the original of Cuvier's "Dauphin à longue symphyse de la mâchoire inférieure, déterré dans une sablière du département des Landes," and to found a new species, *C. valenciennesi*, upon a second specimen that Laurillard (and following him, Gervais) had associated with the type. Subsequently it was pointed out by Abel that the so-called *C. valenciennesi* of Brandt bore sufficient resemblance to Tursiops as to warrant its exclusion from Platanistids altogether. But instead of retaining Laurillard's well-founded specific name for Cuvier's original, he

[1] As pointed out by M. Trouessart (Revue Critique de Paléozoologie, 1906, **10**, p. 205), the genotype of Acrodelphis is *A. letochae* (Brandt). "Contrairement aux usages," continues this author, "M. Abel donne comme 'types' de ce genre *trois* espèces (*A. Letochae, A. Ombonii, A. denticulatus*). Il veut dire, sans doute, que ces trois espèces sont typiques." A discussion of methods of fixing the types of genera was introduced by Witmer Stone, in Science, 1906, **24**, p. 560, and continued by various other systematists.

adopts Brandt's altered designation of *C. macrognathus*.[1] This procedure is entirely arbitrary, and contrary to recognized principles of nomenclature. There is no other course than to regard *C. macrognathus* Brandt as a synonym of *C. macrogenius* Laurillard, and it is in this sense that the former name should be understood in those places where it occurs in the following passage. This quotation from Abel is made in order to allow readers the opportunity of judging for themselves whether we have correctly represented his position: —

"La grande incertitude qui régnait à l'égard du genre Champsodelphis, Gerv., m'a conduit, en donnant une liste des espèces de Schizodelphis, Gerv., et de Champsodelphis, Gerv., à renoncer à ces deux noms et à leur substituer deux autres genres, Cyrtodelphis et Acrodelphis. J'ai mis dans le genre Acrodelphis l'original du 'Dauphin à longue symphyse de la mâchoire inférieure, déterré dans une sablière du département des Landes,' de Cuvier, qui avait été décrit par Brandt sous le nom de *Champsodelphis macrognathus;* j'ai encore joint à ce genre les espèces suivantes: *Acrodelphis lophogenius,* Valenc., *Acrodelphis Ombonii,* Longhi, *Acrodelphis Letochae,* Brandt, et *Acrodelphis Krahuletzi,* Abel. . . .

"Mais des études prolongées sur les Odontocètes des dépôts tertiaires de l'Europe me font voir que le groupement proposé par moi, en 1899, n'est plus satisfaisant. J'ai eu l'occasion de comparer en détail les restes des espèces d'Acrodelphis du bassin de Vienne avec les types belges et les restes des formations miocènes du Nord de l'Allemagne, et je suis, maintenant, d'avis que la diagnose du genre Acrodelphis donnée en 1899 doit être plus restreinte qu'elle ne l'a été alors.

"Comme la mâchoire inférieure du *Champsodelphis macrognathus,* Brandt, se distingue absolument par sa taille et ses dents très espacées d'*Acrodelphis Letochae,* Brandt, et l'*Acrodelphis Ombonii,* Longhi; qu'en outre, la forme de la couronne est très différent dans les deux types; je suis d'avis que l'*Acrodelphis macrognathus,* Brandt, doit être consideré comme le représentant d'un genre différent d'Acrodelphis. Puisque le nom générique de Champsodelphis a été établi par Gervais pour la mâchoire inférieure des Landes qui a d'abord été decrité par Cuvier, mais que cette mâchoire inférieure est absolument différente des espèces décrites plus tard sous le même nom générique: *Champsodelphis* (*Acrodelphis*) *Letochae* et *Champsodelphis* (*Acrodelphis*) *Ombonii,* on doit conserver le nom de Gervais pour *Champsodelphis macrognathus,* tandis que le nom d'Acrodelphis doit rester pour les types beaucoup plus petits, armés de dents beaucoup plus serrées. . . .

[Les types de ces deux genres seraient:]

"1. *Champsodelphis,* Gervais. Type: *Champsodelphis macrognathus,* Brandt.

"2. *Acrodelphis,* Abel. Types: *Acrodelphis Letochae,* Brandt; *Acrodelphis Ombonii,* Longhi; *Acrodelphis denticulatus,* Probst."

Before passing from this subject of nomenclature, it will be instructive to glance at Abel's proposed grouping of Platanistids in general, as set forth in his recent

[1] The reasons proffered by Brandt in justification of this course are thus stated by him: "Ich schlage statt des Namens *macrogenius,* der ohnehin keinen rechten Sinn hat, den bezeichnenderen *macrognathus* vor, weil unter *D. macrogenius* Laurillard zwei Arten stecken, wie Valenciennes nachwies."

memoir. Most authors employ the term Platanistidae to include the two modern subfamilies of Platanistinae and Iniinae, together with the known fossil allies of either. The arrangement proposed by Dr. Theodore Gill in 1872 differs from the one commonly in vogue only in that the minor subdivisions are elevated to the rank of independent families. At that time the Iniidae alone were known to have fossil representatives, and even now opinion is divided as to which of the two groups some of the fossil forms should be referred. Abel's scheme is practically a revival of Gill's arrangement. In his latest memoir (1905) the family Platanistidae is restricted to the genus Platanista itself. The Iniidae of Gill are renamed Acrodelphidae, and made to comprise four subfamilies, one of which includes Delphinapterus and Monodon. In addition, two other independent families are recognized, one being typified by Eurhinodelphis, the other by Saurodelphis. All of these family divisions are considered to have equal rank with the Physeteridae, Ziphiidae, and Delphinidae, and to trace their origin back to Squalodon, but not to Zeuglodon, which is regarded as much too highly specialized to have been the direct ancestor of Squalodontidae. It is suggested that the latter were probably descended from small terrestrial Carnivores, and the Delphinidae from still another group, the Odontocetes being thus of diphyletic origin. Such, in brief, are Abel's more general conclusions.

In order to point out more clearly the exact equivalence between the so-called Acrodelphidae of Abel, and the earlier defined Iniidae of Gill, we may be permitted to reproduce the following summary given by the first-named author at page 129 of his memoir on Odontocetes: —

"Résumé général: Par les caractères de sa dentition et de son crâne, Cyrtodelphis se montre étroitement allié à Argyrocetus, Inia, Pontistes et Pontoporia, comme avec Acrodelphis, et doit donc former un même groupe avec ces formes. Ce groupe correspondrait partiellement aux Platanistides, dans les limites que Zittel a données à cette famille; mais, comme Platanista doit être éliminé, il faut choisir un autre nom. Puisque Acrodelphis est le type fossile le plus primitif de ce groupe, on devra se servir du nom de famille Acrodelphidæ. Nous aurons alors à distinguer:

"ACRODELPHIDAE.

"1. Sous-famille. *Argyrocetinae*: Argyrocetus, Cyrtodelphis, Pontivaga, Ischyorhynchus, Champsodelphis. [s. str.]
"2. " *Acrodelphinae*: Acrodelphis, Heterodelphis
"3. " *Iniinae*: Inia, Pontistes, Pontoporia.
"4. " *Beluginae*: Beluga, Monodon."

With regard to the last subfamily, which should properly be called Delphinapterinæ, the author makes the following observations: "Beluga et Monodon montrent de grandes ressemblances avec les Acrodelphides, tandis qu'ils diffèrent des Delphinides. J'ai, à cause de cela, considéré ces deux genres comme une sous-famille des Acrodelphides; leur origine n'est pas encore éclaircie. Les vertèbres cervicales libres prouvent qu'ils ne descendent pas des Delphinides."

We may now return to the principal matter at issue, namely, a comparison between Lophocetus and certain fossil genera which are regarded as standing in close relations with Inia, and are commonly assigned to the same subfamily. Now, the greater number of fossil Platanistids, or Iniidae in Gill's sense of the term, are remarkable for having the rostrum greatly elongated. In recognition of this fact, Abel divides his so-called Acrodelphidae into two sections, the first three subfamilies listed above being embraced in a section of 'Longirostres,' and the fourth, containing only Delphinapterus and Monodon, constituting the 'Brevirostres.' At first sight these longirostrate Platanistids would seem to present a marked difference from Lophocetus, for, as noted by Harlan, it does not appear that the rostrum in this form was greatly produced, and probably not more than a few inches are missing from it in its present condition. The solidity of the parts composing the muzzle, and general resemblance of the latter to that in brevirostrate Delphinoids, are in harmony with Harlan's conclusion, and so also are the facts of geographical distribution. Longirostrate Platanistids are especially characteristic of European Tertiary deposits, whereas on this side of the Atlantic forms like Champsodelphis,[1] Schizodelphis, Eurhinodelphis, etc., are conspicuously absent, being replaced, apparently, by brevirostrate genera. Probably the explanation of this fact is to be found in differences of physical conditions, such as are to be inferred from the different constitution of the faunas as a whole, and from the different nature of the sediments composing the deposits.

The Miocene deposits of the Middle Atlantic Slope in this country are of characteristically marine type, as indicated by both structural and fossiliferous evidence. On the other hand the corresponding Old World formations from which Delphinoid remains have been obtained are on the whole less clearly of marine origin, and the very circumstance that most of these Delphinoids are longirostrate has been interpreted in the light of adaptation to estuarine or even fluviatile conditions. For as shown by Dollo [2] and various other writers, it is precisely this modification that is oftenest met with in widely diverse orders of vertebrates where forms have become adapted to a littoral or fluviatile existence, as for instance, Lepidosteus among fishes, and Champsosaurus, Phytosaurs, and modern and extinct gavials among reptiles. Dr. J. H. McGregor,[3] in his memoir on the Phytosauria, calls attention to the striking resemblance of the rostrum to the snout of Lepidosteus, and quotes Fraas's observation that its decurved tip "perhaps demonstrates a habit of rooting in mud for food, and catching fishes." Cope,[4] also, noted a somewhat analogous formation of the rostral portion of the jaw in Anoplonassa, and offered a similar explanation. And more recently, the same conclusion has been put forward by Abel [5] in following language: —

[1] The reference to this genus of certain detached teeth and vertebrae from the Maryland Miocene must be regarded as provisional only.

[2] Nouvelle note sur le Champsosaure, Bull. Soc. Belge Géol., 1891, **5**, p. 153.

[3] Memoirs Amer. Mus. Nat. Hist., 1906, **9**, p. 38.

[4] Proc. Amer. Philos. Soc., 1869, **11**, p. 189.

[5] Mem. Mus. Roy. d'Hist. Nat. Belg., 1905, **3**, p. 154.

"Des museaux excessivement longs, tels que nous les trouvons chez Eurhinodelphis, Cyrtodelphis, Acrodelphis, Inia, Pontoporia et Platanista, paraissent être particuliers aux animaux fluviatiles, ou plus précisement, à ceux qui se servent de l'extremité du museau pour fouiller la vase et en faire sortir la nourriture miniscule qui y grouille tout comme chez les oiseaux a long bec (herons, cigognes, bécasses, etc.), oiseaux de marais et de rivages, dont le bec est, physiologiquement, non morphologiquement, identique aux longs rostres des dauphins fluviatiles. Le bec d'une bécasse est entièrement analogue au rostre de Pontoporia."

Enough has now been said by way of emphasizing the purely adaptive feature presented by the elongated rostrum of most Miocene Iniinae (Iniidae of Gill). Therefore, notwithstanding the marked difference in this respect which is exhibited by Lophocetus, we may still place all these forms in close association with the typical existing genus on account of mutual resemblances in other respects. It is unnecessary to enumerate here the various points of agreement that have been observed between Inia and leading longirostrate forms like Champsodelphis and Schizodelphis; for particulars one may refer to Abel's memoir of 1899, already several times quoted. These two genera, according to this author (p. 868), are very intimately related to Inia, but on the other hand Saurodelphis and Eurhinodelphis are more distantly related, and belong probably to a different evolutionary series. Accepting this conclusion, it is interesting to note that Lophocetus displays rather close resemblances to the two first-named genera, and also to Acrodelphis in the restricted sense that the term is now understood by its author. Yet there is even closer affinity between Lophocetus and Inia itself. Schizodelphis and Eurhinodelphis are to be regarded as more primitive than the form we are considering, and more primitive also than modern Iniinae, in that the frontals take part to a considerable extent in forming the gently rounded summit of the cranium, where they are freely exposed, and are either wholly or partly separated from each other by the interparietal. But in Lophocetus the interparietal, which is fused with the steeply inclined supraoccipital, barely excludes the frontals from meeting in the middle line at the vertex of the cranium. Needless to say, too, that the disposition of the parietals in Lophocetus differs radically from that observed in Saurodelphis, where they retain more nearly their primitive arrangement and are in contact with each other in the median line. But as compared with Schizodelphis, the large extent of the parietal surface, the high vertical walls formed by these bones, and their powerful crests for the attachment of jaw muscles, show considerable likeness, and it is only in the more primitive arrangement of the frontals that this portion of the cranium differs very conspicuously in the two genera.

Neither Lophocetus nor any of the best known longirostrate genera resemble Eurhinodelphis in having such highly specialized characters as a completely closed temporal fossa and greatly thickened supraorbital ridges. Closed temporal fossae are the rule among Dolphins proper, Ziphioids, and the Physeteridae, but occur only exceptionally among fossil Platanistids. Like Eurhinodelphis, however, but unlike Inia and Iniopsis, there is no swelling or thickening of the pre-

maxillaries on either side of the narial openings, but these bones are flattened here, and rather widely expanded. Lophocetus shows the same squarish excavation of the maxillaries on either side of the vertex that occurs in modern Iniinae, and also in Pontistes and Iniopsis, but in none of these do the maxillary fossae have such prominent borders. A peculiar feature of Lophocetus, as compared with both recent and fossil Iniinae, is that the prominence formed by the nasals and frontals immediately behind the narial apertures is deeply cleft in a longitudinal direction. Moreover, in Inia this eminence is formed almost entirely by the frontals, which enclose the interparietal between their upturned borders posteriorly, and completely cover the nasals at the vertex in front. But in Lophocetus the frontals scarcely appear in this region, and the divided, nodulose nasals are conspicuously developed, alone forming with the mesethmoid the posterior wall of the external nares. This wall is relatively broader and less convex in a transverse direction than in Inia, but by no means presents the well-defined quadrate surface that is so strongly marked a feature of Iniopsis. The characters of the basicranial axis, and especially the arrangement of palatine and pterygoid elements, point to a closer relationship with Inia than with any known fossil form.

It is to be regretted that, owing to the imperfect condition of the specimen, comparisons cannot be made between Lophocetus and other Iniinae with respect to the dentition and extremity of the snout. One is perhaps permitted to infer from the general agreement in other respects that the dentition had become polyodont-homodont, and that teeth were still borne by the extremity of the premaxillary. The deep fissure separating these last-named bones in advance of the mesethmoid is probably without greater significance than the fused condition of the interparietal, both of which are regarded as old-age characteristics. On the whole, considerable reason is found for supposing Lophocetus to belong to the ancestral line from which modern Iniinæ are directly descended. Saurodelphis, on the basis of its dentition, would be regarded as more primitive than any of these forms, and Eurhinodelphis, with its edentulous premaxillary resembling that of Ziphioids, would be considered more highly specialized. Further material is necessary, however, before one can speak confidently in regard to the direct line of succession. We may conclude this part of the discussion by reproducing the scheme devised by Abel [1] for showing at a glance his views of phylogenetic and other relations.

[1] Mém. Musée Roy. d'Hist. Nat. Belg. 1901, **1**: 39.

PHYLOGENY OF ODONTOCETES.

Ziphius
Oligodont-pseudoheterodont
Pmx and *Mx* edentulous.

Mesoplodon
Oligodont-pseudoheterodont
Pmx edentulous, *Mx* with rudimentary teeth in the gums.

Pmx forming tip of rostrum.

Ziphirostrum
Polyodont-pseudoheterodont
Pmx edentulous, *Mx* with functional teeth.

Eurhinodelphis
Polyodont-homodont
Pmx edentulous, *Mx* with functional teeth.

Inia, Pontoporia
Polyodont-homodont.

Delphinus, "Cyrtodelphis,"
Polyodont-homodont, last vestiges of heterodont dentition among Delphinoids.

Phocaena, Neomeris
Polyodont-heterodont,
Pmx dentate.

Saurodelphis
Polyodont-pseudohomodont.

Neosqualodon, Squalodon
Polyodont-heterodont, *Pmx* dentate.

Microzeuglodon.
Oligodont-heterodont,
Pmx dentate.

We have substituted the genus Microzeuglodon, instead of Zeuglodon, as the initial member of the above series, in accordance with the author's most recent suggestion, published since the table first appeared. The opinion of most modern writers regarding the impossibility of viewing Zeuglodon as the ancestor of Squalodonts is accepted by Abel, who announces further the following general conclusions: —

1. The genus Squalodon is not descended from Zeuglodon.
2. The precursor of Squalodonts is to be sought for among small Archaeoceti, probably in Microzeuglodon.
3. The most primitive Squalodont known at present is Neosqualodon.
4. Microsqualodon represents a lateral offshoot of Squalodonts, transitional between the genera Acrodelphis and Delphinodon (which may be identical).
5. Under Squalodontidae are comprised very heterogeneous types, which should be clearly distinguished from one another.

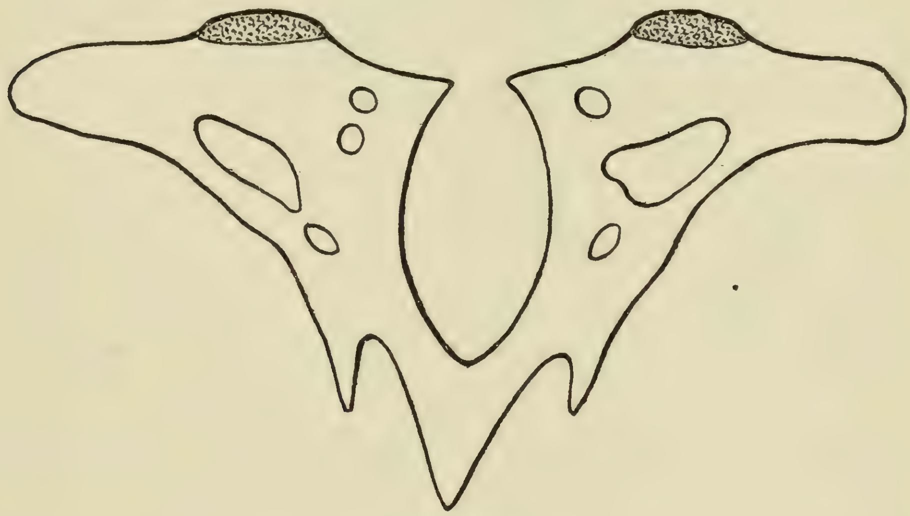


FIGURE *A*.

Transverse section across basal portion of rostrum of Lophocetus as provided by accidental fracture-line seen in Plate 1. × ½.

The more general features of the skull of Lophocetus have now been considered, and the relations they are presumed to indicate have been pointed out. A brief reference may be made here to the illustrations of the type specimen, before passing on to consider the series of cervical vertebrae preserved with the skull.

Plates **1** and **2** show respectively the dorsal and inferior aspects of the cranium, photographed from the actual specimen, and reduced to one-half the natural size. The two transverse fracture-lines appearing in the specimen, one slightly in advance of the position of the antorbital notch (the prominence for which is not preserved), and the other which forms the present termination of the muzzle, have been utilized for preparing the cross-sections shown in Figures *A* and *B*. In these will be noted the wide separation of the premaxillaries, these elements

being stippled in the drawing; the large sinus occupied by the mesethmoid cartilage; and the ample size of the longitudinal vascular canals. In the more posterior cross section (Fig. *A*), none of the sutures are distinctly marked, hence the relations of mesethmoid, pterygoids, and maxillaries at the base of the figure are best understood through comparison with the photograph of these parts given in Plate **2**. In the same plate will be noticed the extremely well preserved periotic elements, which have fortunately been retained in place, notwithstanding the loss of the tympanic bullae. The periotics are more elongate than the corresponding elements in Inia, with more bulbous promontory, and more strongly developed processes for attachment with the bullae. It is noteworthy that in both elements the stapes still remains seated in its proper orifice. The opening seen on the inner side of the periotics in Plate **2**, and also of the natural size in

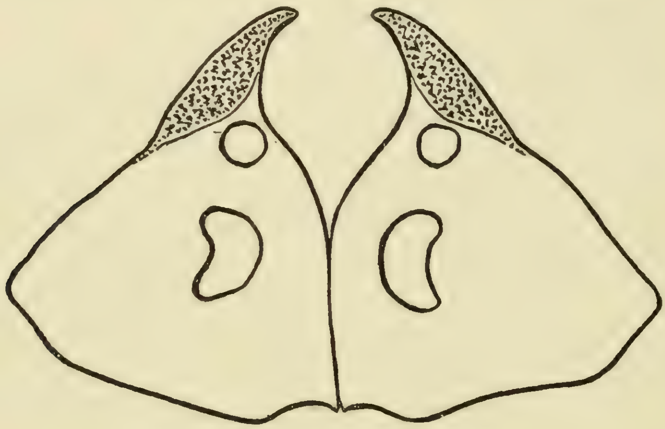


FIGURE *B*.

Transverse section of rostrum in the type of Lophocetus taken at line of fracture along which the forward extremity is severed off. × ½.

Plate **4**, Fig. 2, where a foramen normally occurs, leads directly into the cranial cavity; this is empty, and its walls may be viewed from behind through the foramen magnum.

The occipital border of the skull is indistinctly shown in both plates by reason of the fact that the atlas, within which is included also a portion of the axis, remains firmly cemented to the skull by matrix. It has been allowed to remain in this condition, as have also several characteristic shells (Turritella), to serve for purpose of identification with the original of Harlan's figures, and to leave no possible doubt that the series of cervical vertebrae about to be described belong to the same specimen. No mention of these latter has been made in any previous description. They are proved, however, to belong to the type specimen, by the fact that the axis has been fractured in such manner as to leave a portion of the centrum within the ring of the atlas, against which the remaining portion fits perfectly. The block of matrix in which the verbetrae are embedded without disturbing their natural position is shown in Plate **3**.

Cervical Vertebrae. — The entire series of cervicals is preserved, together with portions of the first three dorsals, all in natural association. Their features may be best described by saying that they reproduce in strikingly similar manner those of the corresponding structures in Inia, the resemblance being much closer than with any other genus. This similitude is found in the form of the individual vertebrae, their relative size, and arrangement with respect to each other, especially as regards the undulating overlap of the neural arches. Saving only that the atlas is more transversely elongate in Lophocetus than in the modern genus, it might be referred with equal propriety to either, if found in the detached condition. In both forms, the suboval ring of the atlas is of considerable thickness, with feeble neural spines and abbreviate transverse processes, the latter pointed slightly upward and outward, and provided below with a large flattened hypapophysial process for articulation with the axis, which has, of course, no distinct odontoid process. Owing to abrasion of the neural arch in the axis and third cervical vertebra, their spinous processes, such as they were, have been entirely destroyed; and the same is true for the last cervical and first three dorsals. All of the intervening cervicals, however, retain traces of very feebly developed neural spines.

On the under side of the series are seen in cross-section the stumps of the downwardly directed transverse processes, now broken off, belonging to the fifth and sixth cervicals. Their relations are apparently identical with those in Inia. On the inferior side, also, the size of the different centra is displayed to best advantage. Measurements taken here of these bodies are given as follows: —

Length of 1st cervical vertebra . . .	3.0 cm. (approximately)
" 2d " "	2.0 " "
" 3d " "	0.6 " "
" 4th " "	0.8 " "
" 5th " "	0.7 " "
" 6th " "	0.8 " "
" 7th " "	1.3 " "
" 1st dorsal "	1.8 " "
" 2d " "	2.3 " "
Height of atlas	8.2 " "
" axis	6.2 " "
" 7th cervical vertebra . . .	6.4 " "
Width of atlas including processes . .	12.4 " "
" axis " " . .	10.0 " "

Delphinus occiduus Leidy.

Plate 4, Fig. 1.

The second type specimen to be considered, although referred by Leidy, who first described it, unqualifiedly to the genus Delphinus, is to be understood rather as belonging to the group of Dolphins proper, that is, to the subfamily Delphinae, than as embraced within the more circumscribed limits of the typical genus. This

limitation is a necessary consequence of the fact that our only knowledge of the form is derived from a fragmentary portion of the rostrum, shown of the natural size in Plate 4, Fig. 1. The original belongs to the J. D. Whitney Collection, presented to the Museum in 1895. It would be superfluous to add anything to Leidy's excellent description (Proc. Acad. Nat. Sci. Phil., 1868, p. 197), which is reproduced in the following paragraph: —

"*Delphinus occiduus.* — An extinct species is indicated by a fossil derived from the upper miocene formation of Half-moon Bay, California, submitted to my examination by Prof. J. D. Whitney. The specimen consists of an intermediate portion of the upper jaw, devoid of teeth, and encrusted with selenite. It measures along the more perfect lateral border 5 inches, and in this extent is occupied with 19 closely set, circular alveoli, rather over two lines in diameter. At the back of the fragment the jaw has measured a little more than 2 inches wide. From this position it gradually tapers for half its length, and then proceeds with parallel sides to the fore end, where it is 10½ lines wide. The palate behind is nearly plane or slightly convex; at its fore part it presents a deep median groove, closed by the apposition of the maxillaries, and this groove is separated only by a narrow ridge from the alveoli. The sides of the maxillaries are slightly concave longitudinally, convex transversely. The intermaxillaries are broken away, leaving a wide, angular gutter between the remains of the maxillaries."

PLATE 1.

Lophocetus calvertensis (Harlan).

Calvert formation (Miocene); Calvert Cliffs Maryland. Type. Cranium viewed from the dorsal aspect, with atlas still engaged by matrix with occiput. Noticeable is the asymmetry of mesethmoid and nasals, and the longitudinal cleft dividing the nodulose summits of the latter, behind which are seen the flange-like frontals. × ½.

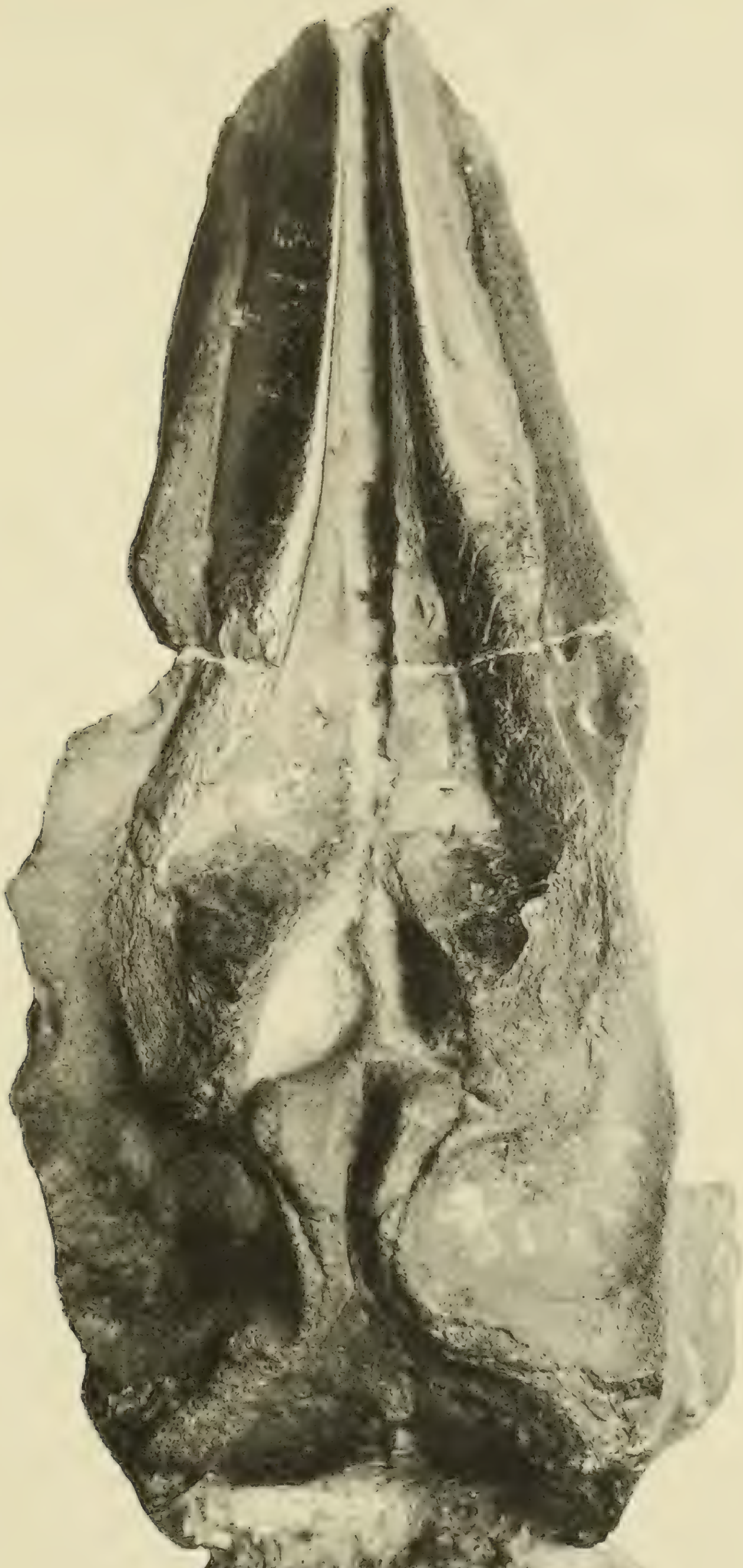


PLATE 2.

Lophocetus calvertensis (Harlan).

Calvert formation (Miocene); Calvert Cliffs, Maryland. Type. Inferior aspect of cranium with atlas still attached to occiput. Especially characteristic are the relations of palatine and pterygoid elements, the latter forming the so-called "pyramidal eminence" of Harlan, and the well-preserved periotic bones. $\times \frac{1}{2}$.

PLATE 3.

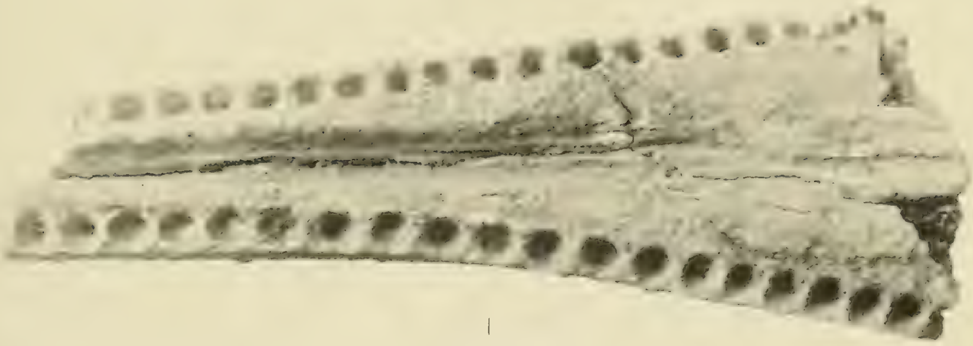
Lophocetus calvertensis (Harlan).

Calvert formation (Miocene); Calvert Cliffs, Maryland. Dorsal aspect of cervical vertebrae belonging to the type specimen. $\times \frac{1}{1}$.

PLATE 4.

Fig. 1. *Delphinus occiduus* (Leidy). Miocene; Half-moon Bay, California. Type. Portion of rostrum. $\times \frac{1}{1}$.

Fig. 2. *Lophocetus calvertensis* (Harlan). Calvert formation (Miocene); Calvert Cliffs, Maryland. Visceral aspect of left periotic, inverted, showing stapes preserved in place. $\times \frac{1}{1}$.



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Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 4.

OBSERVATIONS ON THE TYPE SPECIMEN OF THE FOSSIL CETACEAN *ANOPLONASSA FORCIPATA* COPE.

By Frederick W. True.

With Three Plates.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

July, 1907.

No. 4.—*Observations on the type specimen of the fossil cetacean Anoplonassa forcipata Cope.* By Frederick W. True.

I have recently had an opportunity of examining the type of the remarkable fossil cetacean *Anoplonassa forcipata* Cope, belonging to the Museum of Comparative Zoölogy. This specimen, on which the species was founded by Cope in 1869,[1] consists of the distal portion of a mandible, 191 mm. long. In the original description, Cope remarked that it was obtained, with remains of Mastodon, "not far from Savannah, Georgia." In 1890 he stated that it was from the "phosphatic deposits" of South Carolina.[2] His original description and figures are excellent, but the copies of the latter, published on a reduced scale in 1890, do not represent the specimen accurately. Faithful copies were published in Van Beneden and Gervais's Osteography of the Cetacea.[3]

Few cetologists have published any critical remarks on this interesting species and probably fewer still have ever seen the type and only known specimen. Cope, the original describer, was long in doubt as to its affinities, and, indeed, seems never to have come to a conclusion regarding them.

In 1869 he thought its relationships were with the "aberrant cetacea." "The nearest types," he remarked, "appear to be on the one hand Sirenia, and on the other, Squalodon."[4] In 1890 he actually placed it among the Sirenia, in the family Halitheriidae,[5] but cautiously remarked, "it is by no means certain that it belongs here, and it may be a Cetacean."

His remarks five years later (1895) indicate that he was then convinced that it was a cetacean and that it might be more or less closely related to the ziphioids. In describing his new genus Pelycorhamphus, which he assigns to the Choneziphiidae, he adds:

[1] Proc. Amer. Philos. Soc., **11**, p. 189, Plate 5.

[2] Amer. Nat., **24**, p. 700, Fig. 2. This apparent discrepancy may not be a real one, as Savannah is very close to the boundary line of South Carolina.

[3] Ostéographie des Cétacés, 1880, p. 386, text-fig.

[4] Proc. Amer. Philos. Soc., **11**, p. 189.

[5] Amer. Nat., **24**, Plate 700, Fig. 2.

"It would not be surprising if this genus should prove to be related to *Anoplonassa* Cope, which has the long symphysis mandibuli of the *Physeter,* with the nearly edentulous character of the Choneziphiidae." [1]

So far as I am aware, this is the final statement of Cope as regards Anoplonassa. The view that it was related to the ziphioid whales was not original with him, having been definitely published in Van Beneden and Gervais's Osteography, the title-page of which bears the date of 1880. On page 386 of that work, the authors remark: "We owe to Cope the description of a fossil fragment of a mandible of slender and elongated form, which comprises the greater part of the mandibular symphysis of a cetacean, without doubt related to (*voisin de*) *Hyperoödon* and *Ziphius*." [2]

It is to be noted that Leidy in 1869 assigned Anoplonassa to the Delphinidae, but with the statement that he accepted most of the fossil cetacean species on the authority of Cope, as he had neither time nor opportunity to examine the material on which they were based.[3] Leidy was probably influenced in this case by the view Cope held at the time, that Anoplonassa belonged to the "aberrant cetacea." Leidy's Delphinidae comprised all the Odontoceti, except Squalodon and its allies.

Brandt merely adopted the genus from Leidy, under the general heading of fossil delphinoids of North America.[4] Zittel merely cites the genus among the Ziphiinae,[5] being doubtless influenced by the opinion of Van Beneden and Gervais.

An examination of the type of Anoplonassa, and comparison of it with specimens of recent ziphioids in the National Museum, leave not the slightest doubt in my mind that it belongs to that group of cetaceans. It represents, however, a distinct section of the group. All recent ziphioids have the symphysis of the mandible comparatively short and the rami deep and compressed, while Anoplonassa has a very long symphysis, and it is highly probable that the rami were slender and rounded, somewhat as in Platanista. Although the ziphioids generally have a cranium with a long rostrum, externally the snout is quite short. In Anoplonassa, the snout was doubtless elongated, as in such forms as Platanista and Stenodelphis.

1 Proc. Amer. Philos. Soc., **34**, p. 138.
2 Ostéographie des Cétacés, 1880, p. 386.
3 Journ. Acad. Nat. Sci. Phil., 1869, p. 436.
4 Mem. Acad. St. Petersburg 1873 (7), **20**, p. 289.
5 Handbuch der Paläontologie, 1893, **4**, Vertebrata, p. 179.

The chief features of the mandible of Anoplonassa are as follows: (1) Its slenderness; (2) the slight depth of the symphysis in proportion to its length, and the strong convexity of its sides; (3) the upturned and expanded termination; (4) the pair of large, nearly round, and very slightly depressed terminal alveoli; (5) the rudimentary alveolar groove, with its pair of rather small and shallow elliptical alveoli, not far distant from the terminal pair; (6) the large size and peculiar disposition of the inferior terminal foramina.

It is a well-known fact that in Mesoplodon and other existing genera of ziphioids, the superior alveolar border of the mandible in young individuals, at least, presents a shallow, more or less rudimentary, alveolar groove, and that in a certain proportion of specimens there are, in addition to the 2 or 4 large teeth, a number of very small, rudimentary teeth, which are imbedded in the integuments, and rest on, or partly in, the groove.

The groove itself occupies rather more than the anterior half of the superior border of the mandible. In Mesoplodon it is interrupted by the deep alveoli of the single pair of large teeth, which in most species are at a considerable distance from the anterior end of the mandible. In young specimens of Berardius, a genus with four large teeth, the interspace between the anterior tooth and the posterior tooth on each side is extremely small, and the rudimentary alveolar groove really begins behind the posterior tooth. In adults, however, the diastema between the anterior and posterior deep alveoli may be as much as 70 mm. This interspace is not depressed, but is rough and pierced by several canals.

In a mandible of *Ziphius cavirostris* 770 mm. long, the alveolar groove has a maximum width of about 9 mm. and a maximum depth of about 5 mm. In another imperfect mandible of Ziphius from an old individual the groove is deeper, especially anteriorly. The maximum depth is about 11 mm. In all the ziphioid mandibles examined, the groove is the broadest at the anterior and posterior ends. The floor of the groove is very uneven, and is pierced by numerous foramina for nutrient vessels and nerves. The edges of the groove in some specimens are quite smooth and straight. In others they are more or less crenulate, producing here and there the appearance of genuine alveoli, but these depressions never have the depth or the regular form of the alveoli of the large teeth.

The groove above described is found in Anoplonassa, with a similar general conformation and relative size. The walls, however, are more strongly crenulate than in specimens of existing ziphioids I have examined.

The opposite walls approach each other more frequently, and in a few places are bridged by transverse septa almost on the level of the superior surface. The groove has in consequence somewhat the appearance of a succession of shallow, elongated alveoli. Except at one point, however, it is improbable that any teeth were implanted in the jaw posterior to the large terminal pair, though some small rudimentary teeth may have been, and probably were, imbedded in the integuments above the groove, as in many specimens of recent ziphioids. At the point on the alveolar groove of Anoplonassa already referred to, at a distance of about 47 mm. posterior to the large terminal alveolus, is a second smaller and shallower one of an elliptical form. On the left side this has a length of about 13 mm., a width of about 7 mm., and a depth of about 3 mm. The floor has a granular appearance similar to that of the anterior alveolus. There can be no doubt that a pair of teeth was originally implanted in the jaw at this point, similar to, but much smaller than, the anterior pair, Anoplonassa in this respect resembling Berardius.

The large anterior pair of alveoli is situated immediately at the tip of the mandible. They occupy the whole width of the extremity of the jaw, which is considerably expanded to receive them. They are separated by a common median wall only about 4 mm. in breadth. Each alveolus is about 23 mm. long, 16 mm. broad, and has a maximum depth of about 5 mm. In the centre of each depression is a papilliform elevation. The whole floor of the alveolus is granular in appearance, as already mentioned, and consists of a fine bony network, surrounding small vascular openings. In these alveoli a pair of large teeth undoubtedly rested, as in Ziphius or Berardius. It is well known that in young ziphioids, and especially in the two genera just mentioned, the teeth are implanted in very deep alveoli, with only the tip projecting above the superior surface of the mandible. As the teeth grow they are pushed out more and more, so that finally their roots are scarcely at all below the superior surface of the jaw. In the meantime the vascular pulp below them ossifies and fills the alveolar cavity almost to the top, and on the upper surface of this bony network rests the root of the mature tooth.

This last stage is shown in the mandible of an adult Ziphius (Cat. No. 49599), from Newport, R.I., in the U. S. National Museum. Here the large anterior alveoli are filled to within about 12 mm. of the free margins with a spongy mass of bone, the upper surface of which is somewhat depressed.

The anterior alveoli of an adult *Berardius bairdii* from Bering Id. present a similar appearance on a larger scale. The resemblance of these

alveoli to those of Anoplonassa is very striking and is, I think, the result of a similar mode of dental growth.

The fragment from the anterior end of the symphysis of the mandible which constitutes the type of Anoplonassa, is nearly straight in its posterior two-thirds, but the tip is quite sharply curved upward, and, as already stated, considerably expanded. Just behind this expanded portion, the jaw is slightly constricted. These characters are, strictly speaking, peculiar to Anoplonassa as compared with recent ziphioids, but in adult or old specimens of Ziphius the superior surface of the symphysial region is curved upward, as in Berardius, although this surface is plane, the end of the jaw is rounded, and the terminal alveoli are directed upward rather than forward.

In cross-section, the type of Anoplonassa is shield-shaped, or rather, triangular, with one plane side (superior) and two convex sides. The chord of the convex sides of the jaw does not exceed the breadth of the superior surface, or in other words, a cross-section of the jaw has nearly the form of an equilateral triangle. On casual examination, it would appear that in Anoplonassa the symphysis is not as deep in proportion to its breadth as in existing ziphioids, but a comparison of measurements shows that in Mesoplodon and Berardius the breadth of the extremity of the jaw is about as great as its depth, and in adult Ziphius the breadth is considerably greater than the depth. It thus becomes obvious that it is not the breadth of the symphysis that makes the jaw of Anoplonassa seem so slender, but its great length. The appearance of the specimen indicates that only a portion of the symphysis has been preserved, and that the whole symphysis was much longer. Even in the fragment, however, the length is 6 times the depth, while in Ziphius and Mesoplodon the length of the complete symphysis is only from $2\frac{1}{3}$ to $5\frac{1}{2}$ times its greatest depth, and in Berardius but 2 times its depth.

It is difficult to conjecture how long the complete symphysis of Anoplonassa was originally, or what was the length of the entire mandible. That the symphysis was much longer than the fragment preserved is, as already stated, extremely probable, since the width at the posterior end of the fragment is only 7 mm. greater than the width immediately behind the posterior pair of alveoli. It is certain that the general conformation of the mandible must have been very different from that of any existing ziphioid, and that it resembled rather the mandible of a sperm whale (Physeter), or of one of the Plantanistidae, such as Platanista or Stenodelphis. If the upper jaw was equally

slender, the head must have resembled that of such long-beaked forms as Platanista, but if the maxillae were expanded, which is improbable, the head itself may have been broad and obtuse, as in Kogia or Physeter, and the lower jaw small and underhung. In either case, the appearance of the animal would be very different from that of any of the existing ziphioids, in which the snout is comparatively short and thick, or, in other words, of the shape commonly called "bottlenosed."

In Anoplonassa, the vessels and nerves which supply the mandible instead of issuing anteriorly through a number of foramina scattered irregularly along the rami in the vicinity of the symphysis, as is usual in some ziphioids and most Delphinidae, emerge close to the tip of the jaw in a nearly symmetrical fashion, there being two large foramina on each side immediately below the alveolus of the terminal tooth, with a smaller one between them. The foramina of each side are joined posteriorly by a quite deep groove, which runs along the inferior surface of the jaw nearly to the end of the fragment. The symphysis is strongly carinate in the median line, the internal edge of each half of the jaw being raised into a prominent ridge, which forms the inner boundary of the groove already mentioned. The keel extends from the tip of the mandible nearly to the end of the fragment, but fades out gradually posteriorly.

A very similar arrangement of foramina and ridges occurs in Ziphius and in Berardius. In the former genus the ridges forming the keel are shorter, and somewhat divergent. The canals extending backward from the anterior terminal foramina are much less strongly developed than in Anoplonassa and run into a large and sharply defined mental foramen, situated in line with the posterior end of the symphysis. The anterior foramina instead of remaining separate, are usually merged together, forming an opening of considerable size.

The conformation of Berardius is similar to that of Ziphius, except that usually the mental foramen assumes the form of a long trough situated a little in front of the posterior end of the symphysis and followed posteriorly by one or more additional foramina. It is probable that at the posterior end of the symphysis of Anoplonassa there was a similar foramen or trough. That it is not found on the type specimen is an additional indication that the posterior end of the symphysis is lacking.

While the form of the alveoli, alveolar groove, and mandibular foramina of Anoplonassa denote clearly that it belongs to the subfamily Ziphiinae, it obviously represents a section of that subfamily distinct

from the section to which the recent genera belong. Leaving out of consideration other fossil forms presently to be mentioned, one might properly separate the Ziphiinae from the Physeteridae and, following J. E. Gray, give them the full rank of a family. The family would be divided into three sections, consisting respectively, (1) of Hyperoödon, (2) the other recent genera, and (3) Anoplonassa.

Very recently Dr. O. Abel has called attention to three fossil forms [1] two of which at least are somewhat closely allied to Anoplonassa. These are *Palaeoziphius scaldensis* (Du Bus), *Cetorhynchus atavus* Abel and *Mioziphius belgicus* Abel, all from the Upper Miocene of Antwerp. Of these, *P. scaldensis* is considered by Abel to be the oldest. The size of the mandible is about the same as in Anoplonassa. The length of the entire symphysis in proportion to its depth is about the same as the length of the fragment of the symphysis of Anoplonassa to its depth. Palaeoziphius, however, has 14 alveoli on each side, between most of which are well-formed septa whose upper surface is in the same plane with the upper surface of the jaw. Dr. Abel states that the anterior end of the jaw is slightly expanded, but the figure which accompanies his description does not indicate such an expansion, and we may suppose that it is at best only slight. It is also stated that the symphysial region is semicircular in transverse section and that the end of the jaw is turned upward.

In Cetorhynchus, which is larger than Anoplonassa, the alveolar groove is rudimentary and the septa are imperfect and do not reach the level of the upper surface of the jaw. This upper surface is concave, while on the sides of the mandible there is a deep mental groove. The transverse section of the jaw is semicircular.

In *Mioziphius belgicus* the mandible is much more slender than in Cetorhynchus, but, judged by the symphysial region, is about a half larger than Anoplonassa. Instead of a series of well-formed, or imperfect, alveoli, it has a narrow and shallow rudimentary alveolar groove and two pairs of very large alveoli resembling those of Anoplonassa very closely in some particulars, though the second pair is larger in proportion to the terminal one than in that genus. The terminal alveoli are filled with a mass of cancellous tissue which has a concave surface and a central eminence, as in Anoplonassa, and the alveoli themselves are separated by a narrow median partition. The jaw is expanded at the end where these alveoli are situated. The mass in the posterior alveoli, beside filling the cavity of the latter, appears to protrude considerably

[1] Mém. Mus. Roy. Hist. Nat. Belg., 1905, 3.

beyond the upper surface of the jaw, and in this respect as well as in the larger size of the alveoli themselves, the specimen departs widely from Anoplonassa. I cannot discover that Dr. Abel has given any information regarding the depth of the mandible, but he states that the symphysis is short. In the figure which accompanies the description the jaw is $\frac{1}{4}$ wider at the line of the posterior end of the symphysis than immediately behind the anterior alveoli.

As regards the relations of *Palaeoziphius scaldensis* to *Anoplonassa*, Dr. Abel remarks: —

"The genus *Anoplonassa*, from the Phosphate Beds of Savannah (Georgia), represents a phase of development in which the alveolar canals of the mandible have become rudimentary, with two pairs of teeth [*i. e.*, alveoli] close together; the anterior terminal pair is twice as large as the second pair, which is situated at about the middle of the length of the symphysis. The jaw recalls that of *Squalodon* in general form.

"Although one may without hesitation unite *Anoplonassa* with the ziphioids, until now those stages (of development) have been lacking which lead from *Anoplonassa* to the oldest polyodont and homodont ancestors of the ziphioids. This intermediate form is now represented by the type that Du Bus has described under the name of *Chamsodelphis Scaldensis* [= *Palaeoziphius scaldensis* (Abel)].

"In a comparison with *Anoplonassa* the agreement in size, the length of the symphysis, and the upward inflection of the anterior extremity [of the mandible] immediately strike the eye; the jaw from the Antwerp Boldérien also recalls that of *Squalodon.* But that which at once clearly distinguishes the Antwerp jaw from that of the Phosphate Beds of Savannah, Georgia, is the presence of 14 alveoli in each half of the symphysis." [1]

The foregoing quotation appears to indicate that Dr. Abel considers Palaeoziphius the nearest known ally of Anoplonassa, and hence more closely related to it than are Cetorhynchus or Mioziphius. The reasons which induce him to assign Palaeoziphius to the Ziphiidae are not stated in his paper, so far as I can discover, except as appears in the comparison with Anoplonassa above quoted. The resemblances between the two genera therein mentioned are: (1) the approximately equal size, (2) the expansion of the end of the mandible, (3) its upturned extremity.

As already alluded to, the size of the mandible is somewhat larger in Anoplonassa. The symphysis is certainly somewhat longer, and probably much longer. The expansion of the end of the mandible is much greater; indeed, in Palaeoziphius it is so slight as not to be appreciable in the figure given by Dr. Abel. It is true that Anoplonassa has the

[1] *Loc. cit.*, (1905), p. 92.

end of the jaw upturned, but this is quite probably an age character, as in the recent genus Ziphius old individuals have the extremity of the jaw strongly recurved, while in young individuals the angle between the axis of the symphysis and the axis of the rami is very obtuse.

It appears to me that the evidence that Palaeoziphius belongs to the ziphioids is not convincing, though it is conceivable that the ancestors of the recent genera may have been some such form with a series of functional teeth. It has to be remembered that Palaeoziphius, Cetorhynchus, and Mioziphius are all from the upper Miocene, and that Anoplonassa was also probably derived from the Miocene.

In my opinion Mioziphius is a much nearer relative of Anoplonassa than is Palaeoziphius. That it is of larger size and has a shorter symphysis does not seem to me to exclude the idea of close relationship. It is a well-known fact that closely allied recent genera of cetaceans, such as Steno and Sotalia, or Steno and Tursiops, among the Delphinidae, differ greatly in the two characters mentioned. In the genus Mesoplodon the length of the symphysis varies very considerably in different species. In the general conformation of the symphysis, in the general form, details of structure, and relative positions of the alveoli, and in the form of the end of the jaw, Mioziphius certainly exhibits a striking resemblance to Anoplonassa. These characters, I think, greatly outweigh those of size and of length of symphysis, and make it proper to unite the two genera in a separate section of the Ziphiidae.

Certain crania, as well as mandibles, are assigned to *Mioziphius belgicus* by Dr. Abel, though he does not give the evidence on which the reference of the former to that genus and species is based. Presuming that these crania and jaws really do belong to the same species, it will be interesting to consider Cope's view, expressed in 1895, that the cranium known as Pelycorhamphus may belong to the same genus as the jaw known as Anoplonassa.[1]

Cope's description of the cranium of Pelycorhamphus indicates a form sharing some of the characters of Choneziphius, with others of Paracetus, Kogia, etc., and having as a peculiar feature the expansion of the proximal end of the vomer, forming a wide basin which overlaps the maxillary. There appears to be some trace of this latter character in *Mesoplodon layardi*, but nothing resembling it occurs in Mioziphius. It seems, therefore, that if Dr. Abel has correctly associated the mandible No. 3854 of the Brussels Museum with the cranium of Mioziphius, Pelycorhamphus has nothing to do with Anoplonassa. I am by no means

[1] Proc. Amer. Philos. Soc., 1895, **34**, p. 138.

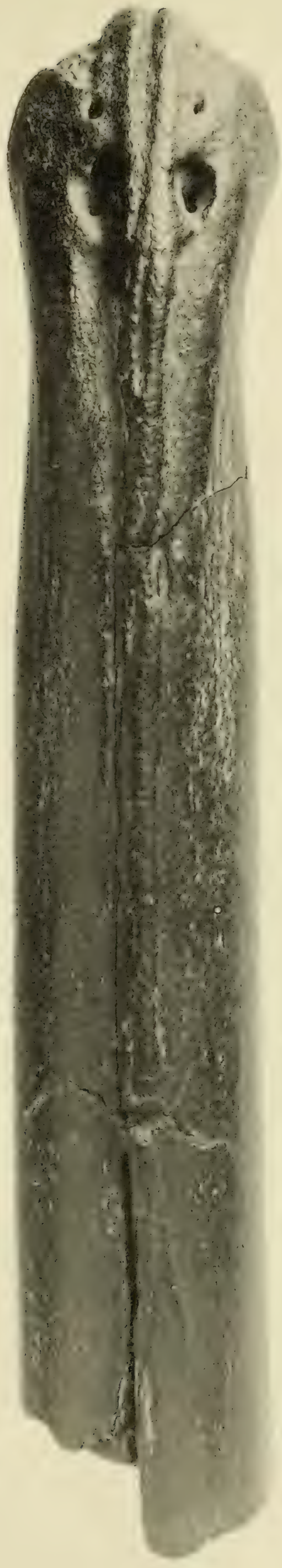
convinced, however, that such is the case, but believe that Cope's surmise may prove correct. Until more material is collected, the question at issue cannot, I think, be satisfactorily settled.

The dimensions of the type specimen of *Anoplonassa forcipata* are as follows: —

Total length	191 mm.
Greatest breadth at the posterior end	34
" " at the anterior end (across the centre of the anterior pair of alveoli)	34
Least breadth behind the anterior pair of alveoli	27
Breadth across centre of posterior " " "	32
Vertical depth at posterior end of fragment	29
" " opposite the posterior pair of alveoli	26
" " " the hind margin of the anterior pair of alveoli	30
Greatest breadth between inner margins of rudimentary alveolar canal posteriorly	24
Breadth between the same, midway from anterior to posterior pairs of alveoli	16
Least breadth between posterior alveoli	14
" " " anterior alveoli	4
Length of posterior alveolus (left)	13
Breadth " " "	7
Length of anterior alveolus (left)	23
Breadth " " "	16

PLATE 1.

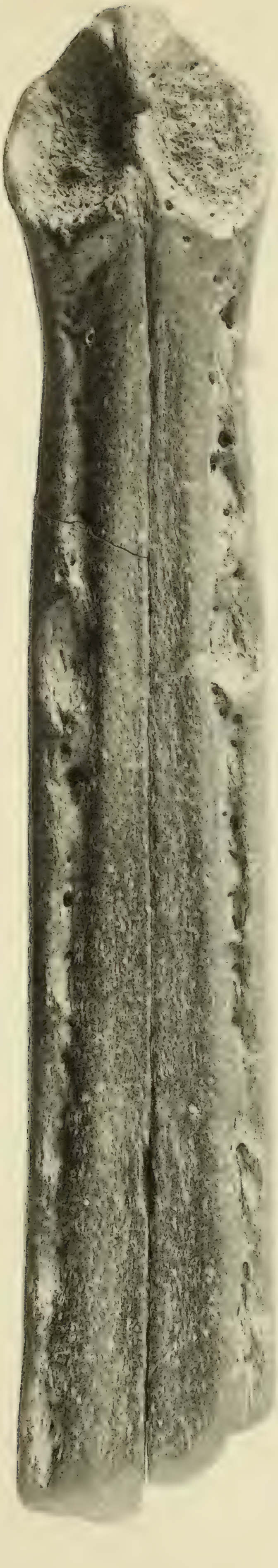
Anoplonassa forcipata Cope. Holotype. Superior aspect.



HELIOTYPE CO., BOSTON.

PLATE 2.

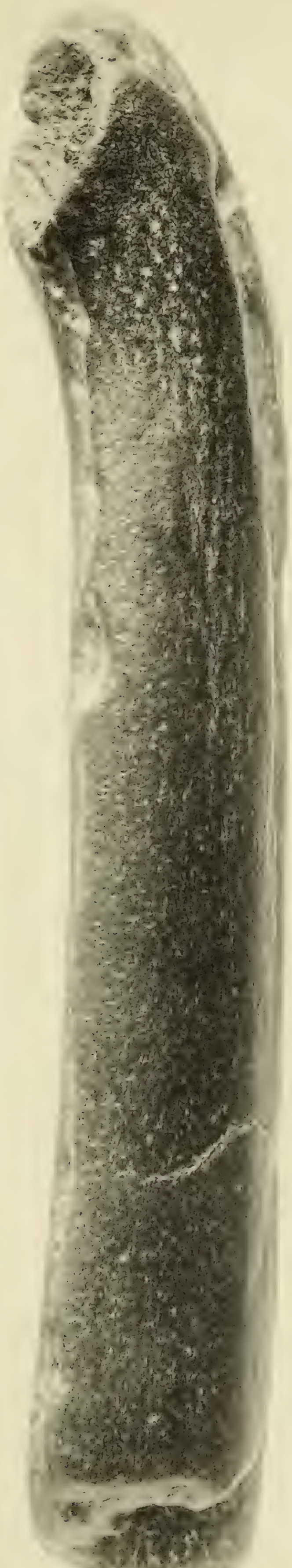
Anoplonassa forcipata Cope. Holotype. Inferior aspect.



HELIOTYPE CO., BOSTON.

PLATE 3.

Anoplonassa forcipata Cope. Holotype. Lateral aspect.



HELIOTYPE CO., BOSTON.

Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. LI. No. 5.

PRELIMINARY REPORT ON THE ECHINI COLLECTED IN 1906, FROM MAY TO DECEMBER, AMONG THE ALEUTIAN ISLANDS, IN BERING SEA, AND ALONG THE COASTS OF KAMTCHATKA, SAKHALIN, KOREA, AND JAPAN, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," IN CHARGE OF LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

By Alexander Agassiz and Hubert Lyman Clark.

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PRINTED FOR THE MUSEUM.
October, 1907.

No. 5 — *Preliminary Report on the Echini collected in* 1906, *from May to December, among the Aleutian Islands, in Bering Sea, and along the coasts of Kamtchatka, Saghalin, Korea, and Japan, by the U. S. Fish Commission Steamer "Albatross," in charge of* Lieut. Commander L. M. Garrett, U. S. N., *Commanding.* By Alexander Agassiz and Hubert Lyman Clark.

The "Albatross" sailed from San Francisco *via* Seattle[1] to Dutch Harbor, Alaska; thence to the westward among the Aleutian Islands, swinging northward and back again to take in Bowers Bank in Bering Sea; from the end of the Aleutian chain northwestward to the Komandorski Islands, then to Petropaulovsk, Kamchatka; thence rounding the southern point of this peninsula and up its western coast to Lat. 51° 40′; from this point southwestward to the Okhotsk Sea along the Kuril Islands to Hakodate, whence the course was taken along the western coast of Hondo, crossing the Sea of Japan to the Korean coast; thence zigzagging southward among the numerous islands at the lower end of the Japanese archipelago, including the northern Linschotens; northward along the eastern Japanese coast, through the Inland Sea and along the outer coast of Hondo again to Hakodate, thus completely circumnavigating Hondo and Kiushiu. From Hakodate the ship cruised northward, west of Hokkaido, up the western coast of Saghalin Island to Lat. 47° 40′; returning and rounding the lower end of the island to Cape Patience, on the eastern side; from Cape Patience south again to the eastward of Hokkaido and back to Hakodate, returning thence to Yokohama, from which point, after a short cruise in Suruga and Sagami bays, the vessel sailed for San Francisco.

The collection of Echini made by the "Albatross" from May 3 to December 10, 1906, is interesting, as it connects the fauna of the deep waters of Alaska and off the Aleutian Islands with that of Japan. The collection from Japanese waters is important, as with those made by Döderlein, we now have a good representation of Japanese Echini living

[1] The route of the "Albatross" is taken from Dredging and Hydrographic Records of the U. S. Fisheries Steamer "Albatross," for the year 1906. Washington, 1907.

in moderate depths, *i. e.*, less than 1000 fathoms. The bulk of the collection from Japan is inside of 300 fathoms; at a few points only was the dredging carried below 700 fathoms. Consequently this collection, like that of Hawaiian Echini we have under examination, fails to connect the littoral with the deep sea fauna.

But as regards the so-called continental region, there are some interesting points of comparison between the Japanese, the Hawaiian, the Alaskan, and the Panamic faunae. In the Panamic fauna there are but few species which encroach on that region either from the North or the South; it has a most typical Echinid fauna connecting with the deep water and abyssal region in which we find the Cystechinidae, Urechinidae, Palaeopneustidae, Ananchytidae, and the like; the nearest relatives of the Panamic Echinid fauna being mainly Indo-Pacific and Pacific species of wide geographical range. We have already called attention to the geographical relation of the Echini collected[1] in the Hawaiian region, which are in the main Pacific and Indo-Pacific.

The Japanese collections indicate affinities with some of the Hawaiian Echini. The absence of Cidaris proper and of the widely spread species of Pacific Echinometra, like *E. mathaei*, *picta*, and *oblonga* and of Diadema, is quite striking. We have only Dorocidaris and Stereocidaris common to both the Hawaiian Islands and Japan. Of the Salenidae of Japan, one extends to Hawaii. A new species of Coelopleurus and the presence of *Aspidodiadema tonsum* indicates the East Indian affinities of Japan. Echinothuriae are common in Japanese waters; one of the species of Asthenosoma is found in 39 fathoms; Phormosoma from 250 to 918, and Sperosoma from 500 to 1766 fathoms. One of the species of Phormosoma from Japan is also found at the Hawaiian Islands. The number of species of Sperosoma is remarkable. The species of Japanese Strongylocentrotus indicate northern Pacific affinities. The species of Temnopleuridae are either identical with (Prionechinus) or allied to (Genocidaris, Pleurechinus) East Indian species. The occurrence of *Hemipedina mirabilis* and of *Phymosoma crenulare* is most interesting. The Japanese collections contain no Hipponoë and only one species of Echinus. It is, however, marked, as is the Hawaiian collection, by the number of its Clypeastroids, especially Laganum of East Indian types, and Scutellidae of Atlantic and northwestern Pacific genera.

A new Echinolampas has been obtained. The only Pourtalesia is *P. laguncula*, which, judging from some fragments, grows to a larger size than was previously known. In the deep waters of the Bering Sea and

[1] Bull. Mus. Comp. Zoöl., 1907, Vol. L, No. 8, p. 232.

off Japan were found Urechinus and Cystechinus, and among Palaeopneustidae one species of Meijerea is common to Bering Sea and the Hawaiian Islands. Among the Spatangina we find Gymnopatagus, Lovenia, and Pseudolovenia, both in Japan and the Hawaiian Islands. *Spatangus Lütkeni* of Japan is closely allied to *S. paucituberculatus* of the Hawaiian Islands. *Brissopsis Oldhami* and *luzonica* have a wide range including both Japan and the Hawaiian Islands, and the genus Aceste is also common to both regions. It is interesting to note the occurrence of two species of Echinocardium, of Hemiaster and of Periaster; the last genus is also found in the Hawaiian Islands. A striking difference between the Japanese and Hawaiian faunae is seen in the abundance of Schizasters in the former region and their almost complete absence in the latter. While our Hawaiian collection contains only a single, very small specimen, there are several hundred in the collection from Japan.

It may be of interest to note that of the 49 genera taken by the "Albatross" in the Hawaiian region, only 20 were taken also in Japanese waters, and of the 67 species, only 9 are in the Japanese collection.

DESMOSTICHA Haeckel.

CIDARIDAE Müller.

Dorocidaris Reini Död.

Cidaris (*Dorocidaris*) *Reini* Döderlein, 1887. Jap. Seeigel, p. 7; Taf. 4, figs. 1–7, Taf. 8, figs. 4a–d.

There is a single adult specimen from station 4933. We also refer to this species two young Cidaridae, one 9, the other 13 mm. in diameter, from station 4936. These individuals are remarkable for their short, stout primary spines, which only about equal the diameter of the test and are noticeably swollen above the neck. They are provided with ten or twelve longitudinal ridges but these are not at all serrate, nor is there any indication of granules or prickles anywhere on the spine. These peculiar primaries are yellowish-white, tipped with brown and with two broad rings of the same color. They are unlike the spines of any Cidaroid which we have seen and it is possible that the two specimens are really the young of an hitherto undescribed species.

Station 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 4936. Off Kagoshima Gulf, Japan, 103 fathoms.
Three specimens.

Stereocidaris microtuberculata Yosh.

Cidaris (*Stereocidaris*) *microtuberculatus* Yoshiwara, 1898. Ann. Zoöl. Jap., **2**, p. 57.

There is a single specimen of this species, which is notable for its large size. The horizontal diameter measures 86 mm., which is considerably more than that of any specimen of Stereocidaris hitherto recorded. Yoshiwara's largest specimen of this species measured 66 mm. As the pedicellariae have never been described, it may be said here that they are very similar to those of *S. leucacantha* A. Ag. and Cl. and cannot be distinguished from them with certainty. The globiferous, both large and small, are very abundant, but the tridentate seem to be very rare.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.

One specimen.

Stereocidaris sceptriferoides Död.

Cidaris (*Stereocidaris*) *sceptriferoides* Döderlein, 1887. Jap. Seeigel, p. 5, Taf. 2, figs. 12–17, Taf. 8, figs. 3a–e.

This rare species is represented by a single small specimen, which agrees well with Döderlein's description and figures, except that the secondaries are not pure white but are tinged with brown, and the test is distinctly brown. Döderlein's figures of the pedicellariae, although not incorrect, do not do justice to their remarkably slender form. Moreover, in many of them the valves have a conspicuous unpaired end tooth and the opening is about one-third of the length. They are thus almost identical with those Mortensen figures as characteristic of his new genus, Schizocidaris. **1903**, Ingolf Exp. Ech., Pt. I, Pl. 10, figs. 25 and 28. If that genus is to be recognized, this species must certainly be placed in it, although it is in other respects very evidently a Stereocidaris.

Station 4968. Between Kobe and Yokohama, Japan, 253 fathoms.

One specimen.

Anomocidaris japonica A. Ag. and Clark.

Dorocidaris japonica Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 76.

Cidaris (*Stereocidaris*) *japonica* Döderlein, 1887. Jap. Seeigel, p. 6, Taf. 3, figs. 1–20; Taf. 8, figs. 1a–h.

Cidaris (*Stereocidaris*) *tenuispinus* Yoshiwara, 1898. Ann. Zoöl. Jap. **2**, p. 57.

Anomocidaris tenuispina A. Agassiz and Clark, 1907. Haw. Pacif. Ech. Cid., p. 30; Pl. 11, figs. 6–12, Pl. 12, figs. 18–30, Pl. 31, figs. 5–8.

A large series of this interesting species was taken and we are therefore able to give additional information about it. The conical form of the test shown by the single specimen formerly at our disposal is not characteristic but is found to a greater or less degree in several individuals, none of which, however, are fully grown. The large specimens all have the rounded abactinal surface figured by Döderlein for *japonica* and a careful comparison of Döderlein's description and

figures with Yoshiwara's description and with our numerous specimens, ranging from 11 to 40 mm. in diameter, has satisfied us that *japonica* and *tenuispina* are identical. But we retain the genus Anomocidaris on account of the bare abactinal surface, which is different from that of any other Echinoid in the absence of primary tubercles on the upper coronal plates. In small examples of Stereocidaris and other Cidaridae, on the youngest coronal plate, next to the abactinal system, a primary tubercle is formed which increases in size with the growth of the plate and sooner or later bears a primary spine; in the adult, therefore, the uppermost coronal plate has an imperfect tubercle, the second has a more perfect tubercle which usually carries a spine and the third always has a primary spine. In small examples of Anomocidaris (11 mm. in diameter), there are six coronal plates, of which the uppermost has a well-formed tubercle and the other five carry primary spines, that on the second plate being the longest. As the animal grows, additional plates form abactinally but these have no primary tubercles and often scarcely an areola, while the spineless tubercle on the plate above the longest spine appears to be gradually more or less resorbed. In large specimens there are usually eight, and may be as many as nine, coronal plates, of which the five or six nearest the actinostome carry primaries, while the remaining two or three have no tubercles and only indications of small areolae. As the actinal coronal plates are small and crowded while those on the abactinal surface are very large, the spines are all actinal in position, except the longest which are just at the ambitus. Consequently the abactinal surface is extraordinarily bare, and the genus Anomocidaris is therefore easily recognized. — The primary spines are more slender than in Stereocidaris but show considerable diversity. They frequently taper to the very tip but are often more or less flaring there, and occasionally, in large specimens, are distinctly flattened and slightly widened at the extremity. They are grayish or brownish in color, often with a decidedly olive-green, very rarely a rosy-red, cast; the neck is brown, usually polished and shining, while the narrow collar is commonly dirty whitish, but may be darker than the neck. The primaries around the actinostome show the greatest diversity. In the smallest specimens, they are white, flat, curved at the tip, and distinctly serrate, exactly as Döderlein figures them for *japonica*, but in the large specimens they are dull gray, but little flattened, not at all curved, and with no trace of serrations. Intermediate conditions between the two extremes are common, and the differences appear to be due to age. — The pedicellariae are equally variable, for on some specimens, the large globiferous, such as Döderlein figures for *japonica*, are very common, on others they are rare and on others they seem to be wholly wanting. The diversity of the small globiferous pedicellariae has already been shown by us in "Hawaiian and Pacific Echini: Cidaridae," Plate 11, figs. 6–12 and Plate 12, fig. 18. They intergrade with the large globiferous pedicellariae quite imperceptibly. Tridentate pedicellariae appear to be always absent. — The color of the test and small spines also reveals some diversity. The test is commonly reddish-brown, but it may be greenish or not infrequently dirty whitish; it is almost always darkest abactinally. The small spines are usually distinctly greenish, more or less decidedly lighter on the edges than at the middle, but they may be

simply dirty whitish or have a reddish cast; they are decidedly brightest on the bare abactinal surface, where they are noticeably small but fairly abundant.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.
" 4808. Between Hakodate and Sado Island, Japan, 47 fathoms.
" 4815. Between Hakodate and Sado Island, Japan, 70 fathoms.
" 4817. Between Hakodate and Sado Island, Japan, 61 fathoms.
" 4832. Between Nanao and Tsuruga, Hondo, Japan, 76–79 fathoms.
" 4833. Between Nanao and Tsuruga, Hondo, Japan, 79 fathoms.
" 4842. Between Dogo Island and Matsu Shima, Japan, 82 fathoms.
" 4876. Eastern Channel, Korea Strait, 59 fathoms.
" 5092. Uraga Strait, Gulf of Tokyo, 70 fathoms.
" 5094. Uraga Strait, Gulf of Tokyo, 88 fathoms.

Forty-nine specimens.

Goniocidaris biserialis Död.

Stephanocidaris biserialis Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 79.
Goniocidaris biserialis Döderlein, 1887. Jap. Seeigel, p. 10. Taf. 5; Taf. 8, fig. 8.

A very good series of this species was taken, ranging in size from 7 to 27 mm. The color shows considerable diversity, as the test and small spines may be yellow, olive-green, brown, or brownish-red. The primaries are uniformly dull, but they are more or less encrusted with sponges, bryozoans, worm-tubes, etc., and the color is thus often considerably modified.

Station 4875. Eastern channel, Korea Strait, 59 fathoms.
" 4876. Eastern channel, Korea Strait, 59 fathoms.
" 4877. Eastern channel, Korea Strait, 59 fathoms.
" 4879. Eastern channel, Korea Strait, 59 fathoms.
" 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4936. Off Kagoshima Gulf, Japan, 103 fathoms.

Thirty-six specimens.

Goniocidaris clypeata Död.

Goniocidaris clypeata Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 82.

A good series of this curious species, ranging from 7 to 20 mm. in diameter, was taken, some of which are remarkably like some specimens of *florigera*. There seem to be, however, constant differences between the two species. The remarkable diversity revealed by the primary spines of these specimens is noteworthy, for some are tapering, only slightly thorny, and not at all expanded at either base or tip (young spines may even be perfectly smooth and tapering), while others, more or less conspicuously prickly, are expanded either at the base or at the tip or at both, and all kinds of intermediate types occur. The color of the test is usually reddish-brown, but may be much lighter. The secondary spines are light brownish. The primaries are gray

or whitish or even bright rose-red. The tuberculation of the median ambulacral area varies greatly; for, while in most specimens, each plate carries two or three small tubercles in addition to the large marginal one, so that the appearance of the area is much like that of *florigera*, in other specimens the middle of each ambulacrum is more or less sunken and bare as in *tubaria;* the two extremes, however, intergrade very evidently.

Station 4891. Southwest of Goto Islands, Japan, 181 fathoms.
" 4900. Southwest of Goto Islands, Japan, 139 fathoms.
" 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 5091. Uraga Strait, Gulf of Tokyo, 197 fathoms.
" 5094. Uraga Strait, Gulf of Tokyo, 88 fathoms.

Nine specimens.

Goniocidaris mikado Död.

Discocidaris (*Cidaris*) *mikado* Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 80.
Goniocidaris mikado Döderlein, 1887. Jap. Seeigel, p. 15, Taf. 7; Taf. 8, figs. 6, 9–18.

A small series of this species is in the collection, ranging from 8 to 21 mm. in diameter. Specimens at any age are readily recognized by the remarkable, very small, nearly spherical miliary spines. The color, very light fawn, nearly cream-white, shows little variety.

Station 4893. Southwest of Goto Islands, 95–106 fathoms.
" 4894. Southwest of Goto Islands, 95 fathoms.
" 4895. Southwest of Goto Islands, 95 fathoms.
" 5070. Suruga Gulf, Japan, 108 fathoms.

Nine specimens.

Aporocidaris fragilis A. Ag. and Cl.

Aporocidaris fragilis A. Agassiz and Clark, 1907. Haw. Pacif. Ech. Cid., p. 37, Pl. 10, figs. 10–21; Pl. 23, figs. 5–8.

There is an excellent series of this species now available, ranging from 8 to 23 mm. in diameter, but there is little to add to our original description. The differences between *fragilis* and *Milleri* appear to be constant, and little diversity is shown. The color of these specimens differs from that of the type in being reddish-rather than yellowish-brown; it is considerably darker than in *Milleri*.

Station 4761. South of Shumagin Islands, Alaska, 1973 fathoms.

Twenty-five specimens.

SALENIDAE Agassiz.

Salenia miliaris A. Ag.

Salenia miliaris A. Agassiz, 1898. Bull. M. C. Z., **32**, p. 74, Pl. 2, figs. 2–4.

Two large specimens, about 17 mm. in diameter, are the only representatives of this species in the collection.

Station 5084. Off Omai Saki Light, Japan, 918 fathoms.

Two specimens.

Salenia cincta A. Ag. and Clark.

This handsome species is closely related to *Pattersoni* A. Ag., but is easily distinguished by the coloration. The test and secondaries, and especially the abactinal system, are deep purple or greenish more or less tinged with purple. The primaries are white, more or less distinctly shaded with green on the upper side, with 12 to 16 broad rings of dull red. The sculpturing of the abactinal system is quite different from that of *Pattersoni*, and tridentate pedicellariae seem to be wanting. The largest specimen is 12 mm. in diameter, and the longest primaries measure 52 mm. The latter are very slender, scarcely a millimeter in diameter, and are distinctly verticillate, though nearly smooth.

Station 4893. Southwest of Goto Islands, Japan, 95–103 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.
" 4936. Off Kagoshima Gulf, Japan, 103 fathoms.

Twelve specimens.

ARBACIADAE Gray.

Coelopleurus maculatus A. Ag. and Clark.

The specimens of Coelopleurus in the collection show no diversity in color or other features, and are strikingly handsome, with polished green primary spines conspicuously spotted on the upper side with scarlet red. The lower side is white, with somewhat indistinct red markings, as though the spots on the upper side showed through. Towards the tip of the spine, on the upper side, the red spots become confluent, so that the distal part of the spine is red for a greater or less distance, though it may be tipped with green or white. The primary spines are sharply triangular, especially near the base, and are distinctly curved towards the tip. The collar is short, rarely over five millimeters in length, dull and usually rough with four or five longitudinal series of coarse granules, on each side. The small actinal primary spines are flat and smooth, pure white, with very conspicuous gray collars extending half their length. — These specimens agree perfectly with the specimens taken by the "Challenger" at Amboina, and with others in the Museum collection from Uraga Channel, Japan, hitherto referred to *C. Maillardi*. It seems to be necessary, however, to distinguish them from that species, for in the type specimen of *Maillardi* from Bourbon, the primary spines are marked with deep purple and the collar is 8 mm. in length, and very finely and uniformly granular. Moreover, the secondary spines in *maculatus* are stout and blunt, rarely having a sharp point, while in *Maillardi* they are strikingly acicular. The largest specimen of *maculatus* before us measures 37 mm. in diameter; the primaries are all broken, but in other specimens they are three or four times the diameter of the test.

Station 4881. Eastern channel, Korea Strait, 40–59 fathoms.
" 4937. Off Kagoshima Gulf, Japan, 58 fathoms.

Five specimens.

ASPIDODIADEMATIDAE Duncan.

Aspidodiadema tonsum A. Ag.

Aspidodiadema tonsum, A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 199.

The specimens taken agree more nearly with the Aspidodiademas taken by the "Challenger" off Cebu, than with those (*nicobaricum*) in our Hawaiian collection.

Station 4980. Between Kobe and Yokohama, Japan, 507 fathoms.
" 5078. Off Omai Saki Light, Japan, 475–514 fathoms.
" 5079. Off Omai Saki Light, Japan, 475–505 fathoms.
" 5080. Off Omai Saki Light, Japan, 505 fathoms.

Fifteen specimens.

ECHINOTHURIDAE Wyville Thomson.

Asthenosoma pellucidum A. Ag.

Asthenosoma pellucidum A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 200.

The specimens are all small, less than 50 mm. in diameter, and their color is darker than that of "Challenger" specimens, but otherwise they are not peculiar.

Station 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.

Three specimens.

Asthenosoma Owstoni A. Ag. and Clark.

Araeosoma Owstoni Mortensen, 1904. Ann. Mag. Nat. Hist., (7) **14**, p. 82, Pl. 2, Pl. 5, figs. 4–9, 11, 18–20.

The specimens before us range in size from 20 to 150 mm., and agree well in all particulars with Mortensen's description, though they show a greater diversity in color. They vary from almost white (the smallest specimens) to nearly brick-red, but the largest specimens are dull, pale purplish. The actinal primary spines are decidedly pinkish, while those on the abactinal surface show only a very slight greenish tinge. The pedicellariae agree entirely with Mortensen's figures.

Station 4875. Eastern channel, Korea Strait, 59 fathoms.
" 4876. Eastern channel, Korea Strait, 59 fathoms.
" 4877. Eastern channel, Korea Strait, 59 fathoms.
" 4946. Between Kagoshima and Kobe, Japan, 39 fathoms.
" 5095. In Uraga Straits, Gulf of Tokyo, 58 fathoms.

Ten specimens.

Asthenosoma tessellatum A. Ag.

Asthenosoma tessellata A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 201.

The single specimen, 140 mm. in diameter, is somewhat damaged, but agrees very well with the "Challenger" specimen, which was taken near Manila.

Station 4943. In Kagoshima Gulf, Japan, 119 fathoms.

One specimen.

Asthenosoma bicolor A. Ag. and Clark.

This species is apparently nearly related to *Owstoni*, but differs in color and in certain features of the test. The coronal plates are low and very numerous, 44 in the interambulacra and 75 in the ambulacra; in *Owstoni* of the same size (125 mm.), the numbers are 38 and 60 respectively. The test is more flexible abactinally than in *Owstoni*, and the bare median ambulacral and interambulacral areas are more marked. The test and spines are dull yellowish actinally, while on the abactinal surface the interambulacra are chiefly yellow and the ambulacra are dull violet. These colors are not sharply defined, but contrast with each other nevertheless. The genital plates in *bicolor* are not so elongated as in *Owstoni*, for they separate only the first pair of interambulacral plates and touch the second, while in *Owstoni* they separate the first two pairs and touch, sometimes nearly separating, the third. In *bicolor*, four of the genitals are remarkable in that the outer part of the plate (*i. e.*, the part distal to the pore) is separated by a regular suture from the remainder of the genital, and thus is a perfectly distinct plate. The pedicellariae of *bicolor* appear to be identical with those of *Owstoni*.

Station 4939. In Kagoshima Gulf, Japan, 85 fathoms.

One specimen.

Asthenosoma pyrochloa A. Ag. and Clark.

This handsome species is very nearly related to the Atlantic species *hystrix*, and is only to be distinguished by the color and some differences in the arrangement of the primary tubercles. The entire test is of a most brilliant vermilion-red, strikingly different from the rich rose-red of *hystrix*. In the ambulacra, on the actinal side, there are two distinct vertical series of tubercles, beginning near the peristome and running nearly or quite to the ambitus. These series lie near together in the median ambulacral area, and on the outer side of each is a shorter and less complete series. In the interambulacra we find very regular series running along the margins close to the ambulacra, and in each area there is a second series on the inner ends of the interambulacral plates. Each plate also carries, not infrequently, one or two additional tubercles. Abactinally each interambulacral plate carries two and often three large tubercles. The secondary and miliary spines are much coarser, and possibly more numerous, than in *hystrix*, so that the general appearance, especially of the abactinal surface, is rather different. The largest specimen is about 190 mm. in diameter.

Station 4919. Off Kagoshima Gulf, Japan, 440 fathoms.
" 5083. Off Omai Saki Light, Japan, 624 fathoms.

Three specimens.

Phormosoma bursarium A. Ag.

Phormosoma bursarium A. Agassiz, 1881. Rept. Chall. Ech., p. 99, Pl. 10 b.

Although these specimens from the northwestern Pacific show such diversity among themselves that they can be divided into two groups, and although neither of

these groups is wholly like the Hawaiian Island form, collected by the "Albatross" in 1902, nevertheless it does not seem to be practicable to distinguish more than a single species. A large proportion of the present collection is made up of young specimens, under 30 mm. in diameter, but the individuals range from 20 to 110 mm.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms
" 4907. Southwest of Koshika Islands, Japan, 406 fathoms.
" 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4913. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4914. Southwest of Koshika Islands, Japan, 427 fathoms.
" 4915. Southwest of Koshika Islands, Japan, 427 fathoms.
" 4957. Between Kagoshima and Kobe, Japan, 437 fathoms.
" 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 4969. Between Kobe and Yokohama, Japan, 587 fathoms.
" 5078. Off Omai Saki Light, Japan, 475–514 fathoms.
" 5082. Off Omai Saki Light, Japan, 662 fathoms.
" 5084. Off Omai Saki Light, Japan, 918 fathoms.
" 5086. Sagami Bay, Hondo, Japan, 292 fathoms.
" 5088. Sagami Bay, Hondo, Japan, 369–405 fathoms.

Thirty specimens.

Phormosoma hoplacantha Wyv. Thoms.

Phormosoma hoplacantha Wyville Thomson, 1877. Voy. Chall. Atlantic, **1**, p. 148, fig. 35.

A fairly good series of a Phormosoma, which seems to be identical with the "Challenger" specimens of *hoplacantha*, was taken at the following stations.

Station 4928. In Colnett Strait, Japan, 1008 fathoms.
" 4956. Between Kagoshima and Kobe, Japan, 720 fathoms.
" 4958. Between Kagoshima and Kobe, Japan, 405 fathoms.
" 4973. Between Kobe and Yokohama, Japan, 600 fathoms.
" 4980. Between Kobe and Yokohama, Japan, 507 fathoms.
" 5078. Off Omai Saki Light, Japan, 475–514 fathoms.
" 5080. Off Omai Saki Light, Japan, 505 fathoms.
" 5082. Off Omai Saki Light, Japan, 662 fathoms.
" 5084. Off Omai Saki Light, Japan, 918 fathoms.
" 5086. Sagami Bay, Hondo, Japan, 292 fathoms.

Thirteen specimens.

Phormosoma tenue A. Ag.

Phormosoma tenuis A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 202.

The specimens referred to this species are of interest from having ophicephalous pedicellariae in addition to the characteristic tridentate ones. As Döderlein (**1906**,

Valdivia Echini, p. 121), has suggested, ophicephalous pedicellariae probably occur in most if not all of the genera proposed by Mortensen. Those of *tenue* are very similar to those figured by D derlein for *Sperosoma durum.* — The color of the "Albatross" specimens is violet above, becoming deep reddish-purple actinally, while the "Challenger" specimens were "yellowish-gray," but in the general appearance and the arrangement of the tubercles there seem to be no important differences between the two series.

Station 4928. In Colnett Strait, Japan, 1008 fathoms.
" 5084. Off Omai Saki Light, Japan, 918 fathoms.

Four specimens.

Sperosoma quincunciale DE MEIJ.

Sperosoma quincunciale de Meijere, 1904. Ech. Siboga-Exp., p. 40, Pl. 13, figs. 166–176.

A number of Echinothurids, closely resembling *P. tenue,* prove on careful examination to be Sperosomas, which we are unable to distinguish from *quincunciale,* though none of the specimens is as large as de Meijere's type. They range from 45 mm. to 170 mm. in diameter and are all more or less deep violet in color. The actinal primary spines are provided with large and conspicuous white "hoofs." The arrangement of the ambulacral pores abactinally is very characteristic.

Station 4957. Between Kagoshima and Kobe, Japan, 437 fathoms.
" 5079. Off Omai Saki, Japan, 475–505 fathoms.
" 5080. Off Omai Saki, Japan, 505 fathoms.

Eight specimens.

Sperosoma biseriatum DÖD.

Sperosoma biseriatum Döderlein, 1901. Zool. Anz., 23, p. 20.

We refer to this species, but not without some hesitation, a badly mutilated specimen of Sperosoma, easily distinguished from the preceding by the arrangement of the ambulacral pores abactinally, which are just as Döderlein (1906, p. 152; Pl. 19, fig. 1) describes and figures them for *biseriatum.* The color and the pedicellariae show slight differences, however, for the test of this specimen was obviously deep purple, and the valves of the pedicellariae have a straight, smooth margin. It is quite possible that this specimen really represents an undescribed species.

Station 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.

One specimen.

Sperosoma giganteum A. AG. and CLARK.

This remarkable Echinothurid measures nearly 320 mm. in its greatest horizontal diameter. The color is very deep purple, almost black when in shadow. The ambulacra are extraordinarily wide, for on the abactinal surface just above the ambitus they measure over 100 mm. while the interambulacra are little over 70. The outer and inner columns in each half of each ambulacrum are made up of re-

markably long, low plates, which just above the ambitus are 25 mm. long and only 5 mm. high. There are no primary tubercles above the ambitus but the whole abactinal surface is rather closely covered with slender secondaries and miliaries. On the actinal surface, primary spines are fairly numerous but show no regular arrangement. Many ambulacral plates have two, and many interambulacral plates four spines. The areolae are small, the diameter usually less than half the height of the plate. The primary spines are seldom 25 mm. long and terminate in a conspicuous white hoof; nearly all are, however, broken off. The pedicellariae are interesting, for in addition to tridentate pedicellariae, similar to those of *Sperosoma biseriatum* Död., but seldom with valves as much as two millimeters long, we find ophicephalous and triphyllous pedicellariae abundant. The latter are not peculiar but the former are almost exactly like those figured by Mortensen (1903, Pl. 14, fig. 23) as characteristic of his proposed new genus "Tromikosoma"! In no other respect, however, does this species resemble that group. Unfortunately only one specimen of this interesting Echinothurid was taken.

Station 5082. Off Omai Saki Light, Japan, 662 fathoms.

One specimen.

ECHINOMETRIDAE Gray.

Strongylocentrotus Dröbachiensis A. Ag.

Echinus Dröbachiensis O. F. Müller, 1776. Prod. Zool. Dan., p. 235.
Strongylocentrotus Dröbachiensis A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 162.

A considerable number of specimens of Strongylocentrotus were collected along the North American coast from British Columbia northwestward, across the Pacific. They show little diversity among themselves and only very slight, if any, differences from specimens collected at Eastport, Maine. For the present at least they may be considered as *Dröbachiensis*.

Bayle Island, British Columbia.
Unalaska, Aleutian Islands.
Atka, Aleutian Islands.
Agattu, Aleutian Islands.
Medni, Komandorski Islands.
Bering, Komandorski Islands.
Petropaulovsk, Siberia.
Forty-three specimens.

Strongylocentrotus nudus A. Ag.

Toxocidaris nuda A. Agassiz, 1863. Proc. Acad. Nat. Sci., Phila., p. 356.
Strongylocentrotus nudus A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 165.

A single immature specimen, only 23 mm. in diameter, seems to be the young of this species, for the arcs of 6 or 7 pairs of pores are nearly vertical and the poriferous zones are correspondingly narrow. The primary tubercles are conspicuous while the other tubercles are few in number and small. The abactinal ambu-

lacral plates show radiating lines on the outer half, corresponding in number to the pairs of pores, as in larger specimens of *nudus*. The test is dull purplish with an evident greenish cast abactinally, and the primary spines and secondaries are more or less greenish. The color is thus quite unlike that of adult *nudus*.

Station 5018. Off Cape Tonin, Saghalin Island, 100 fathoms.

One specimen.

Strongylocentrotus tuberculatus Br.

Echinus tuberculatus Lamarck, 1816. Anim. s. Vert., 3, p. 50.

Strongylocentrotus tuberculatus Brandt, 1835. Prod. Desc. Anim., p. 264.

The specimens are all (except one) large and of a very deep reddish-purple color.

Hakodate.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.

Six specimens.

Strongylocentrotus echinoides A. Ag. and Clark.

It is hard to believe that a littoral Echinoid as common as this species seems to be, and as conspicuous, is still undescribed, but we are entirely at a loss in the attempt to assign it to any known species. The specimens range from 10 to 72 mm. in diameter. The general appearance and coloration in most of the adults, are quite like an Echinus, but the arrangement of the pores, in arcs of seven pairs (six in small specimens) is like Strongylocentrotus, and the pedicellariae of all four kinds are scarcely distinguishable from those of *Dröbachiensis*. The height of the test varies greatly, ranging from .45 of the diameter to .55. The color is equally variable but the test is more or less reddish-white, darkest on the abactinal median interambulacral areas which may be even deep reddish-purple. The small spines are light greenish, but the primaries show considerable diversity. They are commonly dull reddish at the base, becoming very light greenish at the tip, but in some cases, they are wholly green and in others, wholly light red. They are rather long (10–15 mm.), slender and pointed, but not at all numerous. In each interambulacrum, there are two vertical series of 12–20 large tubercles, each of which is flanked on each side by a less regular row of much smaller tubercles. In each ambulacrum, the median area is bounded on each side by a series of 18–30 tubercles, slightly smaller than the largest of those in the interambulacra, and between these two series are two less complete rows of much smaller tubercles. The secondary and miliary spines are very numerous, but are much shorter than the primaries. The abactinal system is small (about .20 of the diameter) and the two posterior ocular plates are in broad contact with the anal system. Pedicellariae, particularly the globiferous ones, are very numerous, and the tridentate are often two millimeters long, not including the stalk.

Station 4777. Petrel Bank, Bering Sea, 43–52 fathoms.
" 4778. Petrel Bank, Bering Sea, 33–43 fathoms.
" 4779. Petrel Bank, Bering Sea, 54–56 fathoms.
" 4782. Off East Cape, Attu Island, Aleutians, 57–59 fathoms.
" 4784. Off East Cape, Attu Island, Aleutians, 135 fathoms.

Station 4786. Between Medni and Bering, Komandorski Islands, 54 fathoms.
" 4787. Between Medni and Bering, Komandorski Islands, 54–57 fathoms.
" 4788. Between Medni and Bering, Komandorski Islands, 56–57 fathoms.
" 4789. Between Medni and Bering, Komandorski Islands, 56 fathoms.
" 4790. Between Medni and Bering, Komandorski Islands, 64 fathoms.
" 4791. Between Medni and Bering, Komandorski Islands, 72–76 fathoms.
" 4792. Between Medni and Bering, Komandorski Islands, 72 fathoms.
" 4794. Off east coast of Kamchatka, 58–69 fathoms.
" 4795. Off east coast of Kamchatka, 48–69 fathoms.
" 4796. Off east coast of Kamchatka, 48 fathoms.
" 4804. Off Simushir Island, 229 fathoms.
" 4810. Between Hakodate and Sado Island, Japan, 90-195 fathoms.
" 4822. Between Nanao and Tsuruga, Hondo, Japan, 130 fathoms.
" 4982. Between Hakodate and Otaru, Hokkaido, Japan, 390–428 fathoms.
" 4987. Between Hakodate and Otaru, Hokkaido, Japan, 59 fathoms.
" 4993. Between Otaru, Hokkaido, and Korsakov, Saghalin, 142 fathoms.
" 4996. Between Otaru, Hokkaido, and Korsakov, Saghalin, 86 fathoms.
" 5016. Off eastern coast, southern end of Saghalin, 64 fathoms.
" 5041. Off southern coast of Hokkaido, Japan, 61–140 fathoms.
" 5048. Between Hakodate and Yokohama, Japan, 129 fathoms.
" 5049. Between Hakodate and Yokohama, Japan, 182 fathoms.

One hundred and sixty-two specimens.

Strongylocentrotus polyacanthus A. Ag. and Clark.

While the specimen to which we have given this name may prove to be an aberrant example of either *Dröbachiensis* or *purpuratus*, it seems best to recognize it now as a distinct species. It may be distinguished by the very numerous short spines, the primaries little exceeding the secondaries in either length (6–8 mm.) or thickness; the numerous (25) coronal plates; and the color. The test is 73 mm. in diameter and both it and the spines are dull rose-purple. The pairs of pores are in oblique, but little curved, arcs of six. Each coronal plate at the ambitus carries 3–5 primary, 25–35 secondary, and 50–60 miliary tubercles.

Milne Bay, Simushir Island, Kuril Islands, Japan.

One specimen.

Strongylocentrotus pulchellus A. Ag. and Clark.

Although the genital pores are large, it is doubtful whether even the larger of our two specimens is adult, as it is only 17 mm. in diameter. But there can be

little question that they represent an undescribed species, for the arrangement of the pores is very characteristic. The pairs are in very oblique, somewhat curved arcs of five, divided by a secondary tubercle into an inner group of two, and an outer, lower group of three pairs. The vertical series of secondary tubercles thus divides the poriferous zone into an inner and an outer band, the latter somewhat the wider. The globiferous pedicellariae are also very unique, for the expanded basal part of each valve is very wide, .60 of the length of the valve, and the terminal tooth is very long, .25–.35 of the valve length. Tridendate pedicellariae appear to be wanting. The test is very light purplish, noticeably darker abactinally, particularly on the median interambulacral areas; on and around the abactinal system there is a very evident green tinge. The primary spines are light purple, rather abruptly tipped with whitish. The smaller spines are very much lighter. In the smaller specimen (9 mm.), the primary spines are purplish only at base, the terminal part being light greenish and the arcs of pore-pairs are nearly vertical above the ambitus and are uninterrupted.

Station 4794. Off east coast of Kamchatka, 58–69 fathoms.
" 5003. Off southwestern coast of Saghalin Island, 35–38 fathoms.
Two specimens.

TEMNOPLEURIDAE Desor.

Temnopleurus Reynaudi Agass.

Temnopleurus Reynaudi Agassiz, 1846. Ann. Sci. Nat., **6**, p. 360.

The specimens taken by the "Albatross" are all small (9–23 mm.) and show no little diversity. The test is thin and the spines are long and slender. The depth of the pits varies greatly in different specimens, in some cases being so shallow as to be scarcely noticeable. The proportion of height to diameter is also variable, ranging from 40 to 55 per cent. The color of the test varies from dull purple, lighter on the poriferous zones, to yellowish-white, blotched around the abactinal system with red, green, purplish, or brown. The spines are brownish, purplish, greenish or dirty white, sometimes much lighter at base than at tip.

Station 4815. Between Hakodate and Sado Island, Japan, 70 fathoms.
" 4832. Between Nanao and Tsuruga, Hondo, Japan, 76–79 fathoms.
" 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4902. Southwest of Goto Islands, Japan, 139 fathoms.
" 4904. Southwest of Goto Islands, Japan, 107 fathoms.
" 4931. In Colnett Strait, Japan, 83 fathoms.
" 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 5074. In Suruga Gulf, Japan, 47 fathoms.
" 5095. Off Gulf of Tokyo, Japan, 58 fathoms.
Seventeen specimens.

Temnopleurus toreumaticus Agass.

Cidaris toreumatica Klein, 1734. Nat. Disp. Ech., p. 22, Pl. 10, fig. E.
Temnopleurus toreumaticus Agassiz, 1841. Mon. d'Ech., Obs., p. 7.

There is only a single specimen of this well-known species, taken at Nanao Beach, Japan.

Salmacopsis olivacea Död.

Salmacopsis olivacea Döderlein, 1885. Arch. f. Naturg., Jahrg., **51**, Bd. 1, p. 93.

These specimens differ from Döderlein's in their larger size and decidedly greener color. The largest are over 25 mm. in diameter.

Station 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4937. In Kagoshima Gulf, Japan, 58 fathoms.

Five specimens.

Pleurechinus variabilis Död.

Pleurechinus variabilis Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 90.

The specimens are small (8–11 mm.) and show little diversity.

Station 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 5068. In Suruga Gulf, Japan, 77–131 fathoms.

Three specimens.

Pleurechinus variegatus Mort.

Pleurechinus variegatus Mortensen, 1904. Dan. Exp. Siam: Ech., p. 84; Pl. 1, figs. 5, 6, 8, 19; Pl. 2, fig. 6.

This species is not readily distinguished from the preceding one unless at least a part of an interambulacrum is cleaned, yet the banding of the primaries, and the usual absence at their tips of a terminal thorn, are features of *variegatus* recognizable with a good lens. The specimens before us have scarcely a trace of red on the primaries, but they are not otherwise peculiar.

Station 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 5095. Off Gulf of Tokyo, Japan, 58 fathoms.

Three specimens.

Prionechinus Agassizii Wood-Mas. and Alc.

Prionechinus Agassizii Wood-Mason and Alcock, 1891. Ann. Mag. Nat. Hist., (6) **8**, p. 441.

Our specimens agree so well with the description and figures of Döderlein (**1906**, p. 194; Pl. 24, fig. 1; Pl. 35, fig. 7) that there can be little question of their identity with his specimen. They show striking diversity in color, however, for while one is pure white, a second has the test pale brown and the very base of the spines tinged with olive, and the third has the tubercles and the basal half of all the larger spines pale red.

Station 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 4967. Between Kobe and Yokohama, Japan, 244–253 fathoms.
" 5086. Sagami Bay, Hondo, Japan, 292 fathoms.
Three specimens.

Prionechinus ruber A. Ag. and Clark.

This species may be recognized by the following combination of characters. The test and abactinal system show little evidence of sculpturing; the anal system is covered by ten to twenty plates, of which one is somewhat larger than the others; there are ten large buccal plates, each with a well developed tube-foot, and between these plates and the mouth the membrane is closely covered with small plates; the primary spines are nearly or quite smooth and rather sharply pointed; the test and basal half of the larger spines are red, while the tips of the spines and some of the tubercles are pure white. The larger specimen is 11 mm. in diameter.

Station 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 4967. Between Kobe and Yokohama, Japan, 244–253 fathoms.
Two specimens.

Genocidaris apodus A. Ag. and Clark.

This interesting species is easily recognized by the very large anal plate, the long primary spines which when unbroken exceed the diameter of the test, and the presence of only five large buccal plates, provided with a tube-foot. The second plate of each pair is rudimentary and carries no pedicel. There are no other plates on the buccal membrane. The test is very distinctly sculptured, but the abactinal system is nearly smooth and carries very few (15–25) small tubercles. The genital pores are large, in the centre of a slight elevation. The abactinal system is very large, its diameter sixty per cent or more of that of the test. The test and spines are white, but in the smallest specimen (the only one with unbroken spines) the terminal half of the longer primaries is red. The largest specimen is only 7 mm. in diameter.

Station 4891. Southwest of Goto Islands, Japan, 181 fathoms.
" 4904. Southwest of Goto Islands, Japan, 107 fathoms.
Three specimens.

TRIPLECHINIDAE A. Ag.

Hemipedina mirabilis Död.

Hemipedina mirabilis Döderlein, 1885. Arch. f. Naturg., Jahrg., **51**, Bd. 1, p. 96.

The excellent series of specimens now before us confirms our recently expressed opinion (Bull. M. C. Z., 50, p. 245) that this species is quite distinct from *H. indica* de Meij.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.
" 4808. Between Hakodate and Sado Island, Japan, 47 fathoms.
" 4900. Southwest of Goto Islands, Japan, 139 fathoms.
" 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.
" 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 5047. Between Hakodate and Yokohama, Japan, 107 fathoms.
Thirty-seven specimens.

Phymosoma crenulare A. Ag.

Glyptocidaris crenularis A. Agassiz, 1863. Proc. Acad. Nat. Sci. Phila., p. 356.
Phymosoma crenulare A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 151.

The "Albatross" collected a single very fine specimen, 77 mm. in diameter, with the longest spines measuring about 55 mm., and three other much smaller specimens.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.
" 5046. Between Hakodate and Yokohama, Japan, 82 fathoms.
Four specimens.

Echinus lucidus Död.

Echinus lucidus Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 97.

An excellent series of this species shows great diversity in the height of the test and in the length of the primary spines.

Station 4917. Off Kagoshima Gulf, Japan, 361 fathoms.
" 4957. Between Kagoshima and Kobe, Japan, 437 fathoms.
" 4958. Between Kagoshima and Kobe, Japan, 405 fathoms.
" 4959. Between Kagoshima and Kobe, Japan, 405–578 fathoms.
" 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 4980. Between Kobe and Yokohama, Japan, 507 fathoms.
" 5048. Between Hakodate and Yokohama, Japan, 129 fathoms.
" 5049. Between Hakodate and Yokohama, Japan, 182 fathoms.
" 5051. Between Hakodate and Yokohama, Japan, 399 fathoms.
" 5078. Off Omai Saki Light, Japan, 475–514 fathoms.
" 5079. Off Omai Saki Light, Japan, 475–505 fathoms.
" 5082. Off Omai Saki Light, Japan, 662 fathoms.
" 5083. Off Omai Saki Light, Japan, 624 fathoms.
" 5084. Off Omai Saki Light, Japan, 918 fathoms.
" 5088. Sagami Bay, Japan, 369–405 fathoms.
Fifty-six specimens.

CLYPEASTRIDAE Agassiz.

ECHINANTHIDAE A. Agassiz.

Clypeaster virescens Död.

Clypeaster virescens Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 102.

The species of Clypeaster in this collection seem to represent but a single species (except possibly one of the very young ones), and we refer them with little doubt to this form, which Döderlein found not uncommon in Sagami Bay. They range from 14 to 114 mm. in length, and the largest is 108 mm. wide and 24 mm. high.

Station 4877. Eastern channel, Korea Strait, 59 fathoms.
" 4884. Between Nagasaki and Kagoshima, Japan, 53 fathoms.
" 4885. Between Nagasaki and Kagoshima, Japan, 53 fathoms.
" 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4894. Southwest of Goto Islands, Japan, 95 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4937. Kagoshima Gulf, Japan, 58 fathoms.
" 4948. Between Kagoshima and Kobe, Japan, 65 fathoms.
" 5071. In Suruga Gulf, Japan, 57 fathoms.
" 5095. Gulf of Tokyo, Japan, 58 fathoms.

Fourteen specimens.

LAGANIDAE Desor. (Emended.)

Laganum fudsiyama Död.

Laganum fudsiyama Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 104.

A number of large Laganidae are apparently the adults of this species. They range from 50 to 71 mm. in long diameter.

Station 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 4966. Between Kobe and Yokohama, Japan, 244–290 fathoms.
" 4967. Between Kobe and Yokohama, Japan, 244–253 fathoms.
" 5091. Off Gulf of Tokyo, Japan, 197 fathoms.

Thirty-one specimens.

Laganum pellucidum Död.

Peronella (Laganum) pellucida Döderlein, 1885. Arch. f. Naturg., **51**, Bd. 1, p. 104.

Although the specimens available are bare tests, there can be no mistaking this easily recognized species.

Station 4885. Between Nagasaki and Kagoshima, Japan, 53 fathoms.

Two specimens.

Laganum diploporum A. Ag. and Clark.

This interesting species resembles *strigatum* A. Ag. and Cl. in the form of the test and the shape of the petals. But the sutures between the plates are scarcely visible, and the color is commonly light green, often yellowish, sometimes brownish. The striking characteristic, however, is the presence of *six* genital pores, two of which are in the posterior interambulacrum. Of the 54 specimens with an uninjured abactinal system, 34 show the *six* pores plainly; of the remaining 20, 17 are under 20 mm. in length, and most of them have no genital pores, at least in the posterior interambulacrum. One specimen, 22 mm. long, has five small pores, but the one in the posterior interambulacrum is at the extreme right hand side of that area. A specimen 37 mm. long, and another 43 mm., apparently have only one pore in the posterior interambulacrum, but under the microscope it becomes evident that this pore is formed by the fusion of two. The steps in the history of such a fusion are all shown in the large series of specimens available. The great majority of the specimens are circular or nearly so, but some of the smaller ones are slightly elongated. The most elongated specimen measures 28 by 26 mm., while the largest ones are 38 × 38.5, 40 × 42, and 43 × 42. The smallest is only 8 mm. in diameter.

Station 4885. Between Nagasaki and Kagoshima, Japan, 53 fathoms.
" 4888. Between Nagasaki and Kagoshima, Japan, 71 fathoms.
" 4893. Southwest of Goto Islands, Japan, 95–106 fathoms.
" 4895. Southwest of Goto Islands, Japan, 95 fathoms.
" 4902. Southwest of Goto Islands, Japan, 139 fathoms.
" 4904. Southwest of Goto Islands, Japan, 107 fathoms.
" 4933. Off Kagoshima Gulf, Japan, 152 fathoms.
" 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.
" 4937. Off Kagoshima Gulf, Japan, 58 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.
" 5070. Suruga Gulf, Japan, 108 fathoms.
" 5092. Off Gulf of Tokyo, Japan, 70 fathoms.

Fifty-six specimens.

SCUTELLIDAE Agassiz.

Echinarachnius excentricus Val.

Scutella excentrica Eschscholtz, 1829. Zoöl. Atl., Pl. 20, fig. 2.
Echinarachnius excentricus Valenciennes, 1846. Voy. Venus. Zooph., Pl. 10.

There is a good series of twenty-four specimens of this curious species from Union Bay, Bayne Island, British Columbia.

Echinarachnius mirabilis A. Ag.

Scaphechinus mirabilis Barnard Mss., A. Agassiz, 1863. Proc. Acad. Nat. Sci., Phila., p. 359.
Echinarachnius mirabilis A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 107.

There are numerous sand-dollars in the collection, which appear to belong to this species.

Station 4786. Between Medni and Bering, Komandorski Islands, 54 fathoms.
" 4787. Between Medni and Bering, Komandorski Islands, 54–57 fathoms.
" 4794. Off East Coast of Kamchatka, 58–69 fathoms.
" 4795. Off East Coast of Kamchatka, 48–69 fathoms.
" 4796. Off East Coast of Kamchatka, 48 fathoms.

Sixty specimens.

PETALOSTICHA Haeckel.

CASSIDULIDAE Agassiz.

NUCLEOLIDAE Agassiz.

Echinolampas sternopetala A. Ag. and Clark.

This species may be at once recognized by its narrow apetaloid ambulacra, with moderately long, straight, unequal poriferous zones. The color is bright yellowish-green. Length, 47 mm.; width, 40 mm.; height, 21 mm. Unpaired ambulacrum (poriferous portion), 12 mm. long, 2.5 mm. wide at open end, with 27 pairs of pores in left zone and 30 in right; right anterior ambulacrum, 15 × 2.5 mm., with 27 pairs of pores in left zone and 37 in right; right posterior ambulacrum, 15 × 2.5 mm., with 32 pairs of pores in left zone and only 25 in right. Anal system covered mainly by three large plates.

Station 4934. Off Kagoshima Gulf, Japan, 103–152 fathoms.

One specimen.

SPATANGIDAE Agassiz.

POURTALESIAE A. Agassiz.

Pourtalesia laguncula A. Ag.

Pourtalesia laguncula A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 205.

A good series of specimens, up to 30 mm. in length, is at hand. There is also a posterior fragment of a much larger individual, in which the anal snout is dorsally flattened and 10 mm. wide. This individual was apparently over 50 mm. long and possibly represents an undescribed species.

Station 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.
" 4906. Southwest of Koshika Islands, Eastern Sea, 369–406 fathoms.
" 4911. Southwest of Koshika Islands, Eastern Sea, 391 fathoms.
" 4912. Southwest of Koshika Islands, Eastern Sea, 391 fathoms.
" 4913. Southwest of Koshika Islands, Eastern Sea, 391 fathoms.
" 4914. Southwest of Koshika Islands, Eastern Sea, 427 fathoms.
" 4915. Southwest of Koshika Islands, Eastern Sea, 427 fathoms.

Station 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 5054. Suruga Gulf, Japan, 282 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.
" 5072. Suruga Gulf, Japan, 148–284 fathoms.

Fifty-six specimens.

URECHINIDAE Lambert. (Emended. A. Agassiz.)

Urechinus naresianus A. Ag.

Urechinus naresianus A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 207.

A series of Urechinus, ranging in length from 30 to 58 mm., does not seem to be distinguishable by any constant character from this cosmopolitan species.

Station 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.
" 5030. 46° 29′ 30″ N. × 145° 46′ E., 1800 fathoms.

Thirteen specimens.

Cystechinus purpureus A. Ag. and Clark.

Although this species is nearly allied to the southern *Wyvillii*, it is distinguished from that species by the more compact abactinal system, having only three genital pores, much smaller and wholly inconspicuous pedicels, and the much deeper purple color, which has little or no tendency to red. The genital plates are more or less approximately square, and the distance from the anterior pore to either of the posterior ones is not much greater than from one of the latter to the other. The test is much lower and the individuals are all smaller than the full-grown *Wyvillii*. Although the tests vary considerably in relative height, the diversity is not so great as is shown in *Urechinus naresianus*, as figured in the "Challenger" Report (Plate XXX a) by A. Agassiz. The plates near the ambitus are very low, as in Urechinus, with which genus this species is an obvious connecting link. The largest specimen is 66 mm. long and 23 mm. high, while another not quite so long is 33 mm. high.

Station 4761. 53° 57′ 30″ N. × 159° 31′ W., 1973 fathoms.
" 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.
" 5030. 46° 29′ 30″ N. × 145° 46′ E., 1800 fathoms.

Nine specimens.

PALAEOPNEUSTIDAE A. Agassiz.

Palaeopneustes fragilis de Meij.

Palaeopneustes fragilis de Meijere, 1903. Tijd. Ned. Dierk. Ver., (2) 8, p. 12.

All of the specimens are large and badly broken, but there is no doubt of their identity with this East Indian species.

Station 4969. Between Kobe and Yokohama, Japan, 587 fathoms.
" 4970. Between Kobe and Yokohama, Japan, 500–649 fathoms.
" 5053. Suruga Gulf, Japan, 503 fathoms.
" 5080. Off Omai Saki Light, 505 fathoms.

Four specimens.

Linopneustes excentricus de Meij.

Linopneustes excentricus de Meijere, 1903. Tijd. Ned. Dierk. Ver., (2) **8**, p. 13.

There is a good series of this Spatangoid, ranging from 24 to 84 mm. in long diameter.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms.
" 4907. Southwest of Koshika Islands, Japan, 406 fathoms.
" 4909. Southwest of Koshika Islands, Japan, 434 fathoms.
" 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4915. Southwest of Koshika Islands, Japan, 427 fathoms.

Eleven specimens and numerous fragments.

Meijerea excentrica A. Ag. and Cl.

Meijerea excentrica A. Agassiz and Clark, 1907. Bull. M. C. Z., **50**, p. 252.

One of the specimens is 100 mm. long, 80 mm. wide and 30 mm. high, and the abactinal system is 52 mm. from the anterior margin. The color of this specimen is a much deeper brown than that of smaller specimens and has a distinct reddish tinge.

Station 4908. Southwest of Koshika Islands, Japan, 434 fathoms.
" 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4914. Southwest of Koshika Islands, Japan, 427 fathoms.
" 4956. Between Kagoshima and Kobe, Japan, 720 fathoms.

Two specimens and numerous fragments.

Meijerea plana A. Ag. and Clark.

At first glance, the individual on which this species is based, might be considered a young specimen of the preceding, but more careful examination makes this seem impossible. The test is 28 mm. long, 22 mm. wide, 4 mm. high at the anterior margin and 9 mm. high at the posterior end, where it is abruptly truncate. The anal system is on this vertical posterior surface. The abactinal system is excentric, 15 mm. from the anterior margin. The actinostome is little sunken and there is practically no labrum. The subanal fasciole is not at all angular and encloses a space 6 mm. wide by 2 mm. high. The shape of the test

and the absence of a conspicuous labrum easily distinguish this species from *excentrica* to which it is otherwise very nearly allied.

Station 4919. Off Kagoshima Gulf, Japan, 440 fathoms.

One specimen.

SPATANGINA Gray.

Spatangus Lütkeni A. Ag.

Spatangus Lütkeni A. Agassiz, 1872. Bull. M. C. Z. 3, p. 57.

The specimens are well preserved but small.

Station 4807. Between Hakodate and Sado Island, Japan, 44–47 fathoms.

" 5047. Between Hakodate and Yokohama, Japan, 107 fathoms.

Six specimens.

Gymnopatagus magnus A. Ag. and Clark.

This fine new species is larger than any of the other members of the genus, our best specimen measuring 98 mm. long, 80 mm. wide, and 30 mm. high. It is much nearer to *valdiviae*, the type of the genus, in the form of the test and petals, than are either of the Hawaiian species, but it differs strikingly from them all in the large number of primary tubercles within the fasciole, particularly in the posterior interambulacrum; the anterior interambulacra each have 25 to 35 tubercles, the lateral have 28 to 32, and the posterior has 25 to 30. The primary spines are 20 to 45 mm. long and almost perfectly smooth, though many show a few scattered, minute teeth and in some cases these are sufficiently numerous to form imperfect whorls. The test and primaries of the largest specimen are pale fawn-color with the numerous small spines lighter, almost silvery-white, but a specimen 80 mm. long is distinctly reddish, almost dull rose-red on some parts of the test.

Station 5082. Off Omai Saki Light, Japan, 662 fathoms.

" 5083. Off Omai Saki Light, Japan, 624 fathoms.

Four specimens.

Lovenia gregalis Alcock.

Lovenia gregalis Alcock, 1893. Journ. Asiat. Soc. Bengal, 62, p. 175.

The Lovenias in this collection all belong to a single species and are more closely allied to *gregalis* than to any other species, although they do not agree in every detail with Alcock's description.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms.

" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.

Five specimens.

Pseudolovenia hirsuta A. Ag. and Cl.

Pseudolovenia hirsuta A. Agassiz and Clark, 1907. Bull. M. C. Z., **50**, p. 255.

These specimens cannot be distinguished from those of the same size from Hawaii.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms.

Two specimens.

Maretia tuberculata A. Ag. and Clark.

This species is not at all like *alta*, *elevata*, or *elliptica*, and although it is very similar to *planulata* in the form of the test and the petals, the latter are narrower and shorter than in that species. The striking character, however, is the presence of few, very large primary tubercles in the anterior and lateral interambulacra, like those of *alta*; there are 1–3 in the anterior and 3–4 in the lateral spaces. The absence of genital pores and the condition of the petals show that the specimen is immature but it is evidently not the young of any known species. The test is 26 mm. long and 22 mm. wide, and the general color is very light purplish-gray.

Station 4875. Eastern channel, Korea Strait, 59 fathoms.

One specimen.

Echinocardium australe Gray.

Echinocardium australe Gray, 1851. Ann. Mag. Nat. Hist., (2) **7**, p. 131.

The only specimen is immature, 14 mm. long, and almost pure white.

Station 4962. Between Kobe and Yokohama, Japan, 36 fathoms.

One specimen.

Echinocardium dubium A. Ag. and Clark.

The occurrence in the northwestern Pacific of an Echinocardium allied to *flavescens* and *pennatifidum* is interesting. This species is certainly very closely allied to these north Atlantic forms, the only differences worthy of note being in the form and position of the anal system and subanal fasciole. The posterior end of the test does not overhang the anal system at all, but the latter is flush with the test; its vertical diameter is noticeably longer than the transverse. The subanal fasciole is nearly circular and not at all pyriform. The color is pale brown with the numerous small spines almost white, when dry. The largest specimen is 31 mm. long.

Station 4965. Between Kobe and Yokohama, Japan, 191 fathoms.
" 5047. Between Hakodate and Yokohama, Japan, 107 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.

Three specimens.

BRISSINA Gray.

Hemiaster gibbosus A. Ag.

Hemiaster gibbosus A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 210.

The large series collected range in size from 10 to 34 mm. long diameter, and many of them seem to be almost spherical.

Station 4913. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4967. Between Kobe and Yokohama, Japan, 244–253 fathoms.
" 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 4970. Between Kobe and Yokohama, Japan, 500–649 fathoms.
" 4971. Between Kobe and Yokohama, Japan, 649 fathoms.
" 4973. Between Kobe and Yokohama, Japan, 600 fathoms.
" 4977. Between Kobe and Yokohama, Japan, 544 fathoms.
" 5053. Suruga Gulf, Japan, 503 fathoms.
" 5054. Suruga Gulf, Japan, 282 fathoms.
" 5056. Suruga Gulf, Japan, 258 fathoms.
" 5083. Off Omai Saki Light, 624 fathoms.
" 5086. Sagami Bay, Hondo, Japan, 292 fathoms.
" 5087. Sagami Bay, Hondo, Japan, 614 fathoms.
" 5088. Sagami Bay, Hondo, Japan, 369–405 fathoms.
" 5093. Off Gulf of Tokyo, Japan, 302 fathoms.

Fifty-five specimens.

Hemiaster globulus A. Ag. and Clark.

The largest Hemiaster collected differs so much from the large specimens of *gibbosus* that we consider it an undescribed species. The test is nearly globular, measuring 36 mm. in length, 35 mm. in width and 33 mm. in height. The posterior end is vertically truncate, while the plastron forms a broad rounded keel. The most striking character, however, is the narrowness of the petals and the length of the posterior pair. In *gibbosus*, the posterior petals are about three-fifths of the length of the lateral ones, while their width is about three-fourths of their own length. In *globulus*, the posterior petals are seven-tenths of the length of the lateral ones, and their width is less than half their own length. In all the specimens of the large series of *gibbosus* no connecting links between the two forms were found. The test is more thickly covered with tubercles and small spines in *globulus* than in *gibbosus*, but the color is not essentially different.

Station 4832. Between Nanao and Tsuruga, Hondo, Japan, 76–79 fathoms.

One specimen.

Brissopsis luzonica A. Ag.

Kleinia luzonica Gray, 1851. Ann. Mag. Nat. Hist., (2) **1**, p. 133.
Brissopsis luzonica A. Agassiz, 1872. Rev. Ech., Pt. 1, p. 95.

There are only a few specimens of this species but they are mostly well preserved.

Station 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.
" 5083. Off Omai Saki Light, Japan, 624 fathoms.
" 5091. Off Gulf of Tokyo, Japan, 197 fathoms.
" 5092. Off Gulf of Tokyo, Japan, 70 fathoms.

Eleven specimens.

Brissopsis Oldhami Alcock.

Brissopsis Oldhami Alcock, 1893. Jour. Asiat. Soc., Bengal, **62**, p. 6 (174).

A large series of this species was taken.

Station 4906. Southwest of Koshika Islands, Japan, 369–406 fathoms.
" 4907. Southwest of Koshika Islands, Japan, 406 fathoms.
" 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4912. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4913. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4915. Southwest of Koshika Islands, Japan, 427 fathoms.
" 4956. Between Kagoshima and Kobe, Japan, 720 fathoms.
" 4957. Between Kagoshima and Kobe, Japan, 437 fathoms.
" 4966. Between Kobe and Yokohama, Japan, 244–290 fathoms.
" 4970. Between Kobe and Yokohama, Japan, 500–649 fathoms.
" 4980. Between Kobe and Yokohama, Japan, 507 fathoms.
" 5053. Suruga Gulf, Japan, 503 fathoms.
" 5054. Suruga Gulf, Japan, 282 fathoms.
" 5082. Off Omai Saki Light, Japan, 662 fathoms.
" 5087. Sagami Bay, Hondo, Japan, 614 fathoms.
" 5088. Sagami Bay, Hondo, Japan, 369–405 fathoms.

Seventy-three specimens.

Aërope fulva A. Ag.

Aërope fulva A. Agassiz, 1898. Bull. M. C. Z., **32**, p. 81.

We refer the fragments of an Aërope, of a bright yellow-brown color, to this Panamic species.

Station 4766. Between Atka Island and Bowers Bank, Bering Sea, 1766 fathoms.

Two specimens (anterior fragments only).

Aceste purpurea A. Ag. and Cl.

Aceste purpurea A. Agassiz and Clark, 1907. Bull. M. C. Z., **50**, p. 259.

The specimens of Aceste collected belong to this Hawaiian species.

Station 4911. Southwest of Koshika Islands, Japan, 391 fathoms.
" 4913. Southwest of Koshika Islands, Japan, 391 fathoms.

Three specimens.

Schizaster japonicus A. Ag.

Schizaster japonicus, A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 212.

There is an excellent series of this species, ranging from 15 to 60 mm. in length.

Station 4939. Kagoshima Gulf, Japan, 85 fathoms.
" 4940. Kagoshima Gulf, Japan, 115 fathoms.
" 4942. Kagoshima Gulf, Japan, 118 fathoms.
" 4943. Kagoshima Gulf, Japan, 119 fathoms.
" 4945. Kagoshima Gulf, Japan, 70 fathoms.
" 4961. Between Kobe and Yokohama, Japan, 33 fathoms.
" 4962. Between Kobe and Yokohama, Japan, 36 fathoms.
" 4964. Between Kobe and Yokohama, Japan, 37 fathoms.

Thirty-one specimens.

Schizaster ventricosus Gray.

Schizaster ventricosus Gray, 1851. Ann. Mag. Nat. Hist., (2) **7**, p. 133.

A remarkably interesting series of this species was taken, ranging from 9 to 74 mm. in length. There is the greatest diversity, shown in the relative length of the anterior and posterior petals and in the angle made by the latter with the longitudinal axis of the body. While it is possible to divide the specimens into three groups, ((1) with short, widely diverging, posterior petals, (2) with long, straight, little diverging, posterior petals, and (3) with very long petals, the posterior pair straight and moderately diverging) it is impossible to draw hard and fast lines between such groups, and although the typical examples of each group are obviously different from each other, it seems best to regard them all as *ventricosus.*

Station 4748. Off Bushy Point, near Yes Bay, Alaska, 185–300 fathoms.
" 4768. Bowers Bank, Bering Sea, 764 fathoms.
" 4775. Bowers Bank, Bering Sea, 584 fathoms.
" 4832. Between Nanao and Tsuruga, Hondo, Japan, 76–79 fathoms.
" 4842. Off Dogo Island, Sea of Japan, 82 fathoms.
" 4968. Between Kobe and Yokohama, Japan, 253 fathoms.
" 4993. Between Otaru, Japan and Korsakov, Saghalin Island, 142 fathoms.
" 5015. Off east coast, southern end of Saghalin Island, 510 fathoms.
" 5029. 48° 22′ 30″ N. × 145° 43′ 30″ W., 440 fathoms.
" 5032. Yezo Strait, Japan, 300–533 fathoms.
" 5033. Yezo Strait, Japan, 533 fathoms.
" 5036. Off south coast of Hokkaido, Japan, 464 fathoms.
" 5037. Off south coast of Hokkaido, Japan, 175–349 fathoms.
" 5039. Off south coast of Hokkaido, Japan, 269–326 fathoms.
" 5040. Off south coast of Hokkaido, Japan, 140–269 fathoms.
" 5045. Off south coast of Hokkaido, Japan, 359 fathoms.
" 5046. Between Hakodate and Yokohama, Japan, 82 fathoms.
" 5047. Between Hakodate and Yokohama, Japan, 107 fathoms.

Station 5049. Between Hakodate and Yokohama, Japan, 182 fathoms.
" 5051. Between Hakodate and Yokohama, Japan, 399 fathoms.
" 5053. Suruga Gulf, Japan, 503 fathoms.
" 5054. Suruga Gulf, Japan, 282 fathoms.
" 5055. Suruga Gulf, Japan, 124 fathoms.
" 5056. Suruga Gulf, Japan, 258 fathoms.
" 5059. Suruga Gulf, Japan, 197–297 fathoms.
" 5067. Suruga Gulf, Japan, 293 fathoms.
" 5072. Suruga Gulf, Japan, 148–284 fathoms.
" 5087. Sagami Bay, Hondo, Japan, 614 fathoms.
" 5088. Sagami Bay, Hondo, Japan, 369–405 fathoms.
" 5091. Off Gulf of Tokyo, Japan, 197 fathoms.
" 5092. Off Gulf of Tokyo, Japan, 70 fathoms.
" 5093. Off Gulf of Tokyo, Japan, 302 fathoms.

Two hundred and seventy-five specimens.

Periaster rotundus A. Ag. and Clark.

This species is extraordinarily like *limicola* from the Gulf of Mexico, as it has two genital pores and the general shape of the test is of that species. The posterior petals are shorter in *rotundus* (just one-half the lateral ones, instead of nearly two-thirds as in *limicola*) and have fewer pairs of pores relatively (less than 65 per cent of the number in the lateral petals instead of over 75 per cent as in *limicola*). The mouth is nearer the centre of the actinal surface in *rotundus* (two-fifths of the long axis from the anterior end, instead of one-third as in *limicola*). The test is 37 mm. long, 35 mm. wide, and 31 mm. high. The color of the test is pale brown, and the numerous spines are silvery-white (dry).

Station 4946. Between Kagoshima and Kobe, Japan, 39 fathoms.

One specimen.

Periaster fragilis A. Ag. and Clark.

The specimen upon which this species is based is obviously immature, and has no genital openings. At first sight it might be mistaken for a young Schizaster; but comparison with specimens of *S. japonicus* and *S. ventricosus* of the same size and smaller shows at once that such is not the case. In young Schizasters the area occupied by the petals and peripetalous fasciole covers most of the abactinal surface, the abactinal system is far back of the center, and the anterior ambulacral furrow is already deep. None of these characters are found in the specimen under discussion. That it is not the young of the preceding species is shown by the extraordinary shortness of the posterior petals, the narrower, flatter test, and the character of the actinostome. The test is 16 mm. long, 14 mm. wide, and 10 mm. high. The lateral petals are 5.3 mm. long and have 18 pairs of pores,

while the posterior petals are 2 mm. long and have only 7 pairs of pores. The labial plate is short and in contact with only one ambulacral plate on each side, and the actinostomal membrane carries only very small plates, while in *rotundus* the labial plate is long and in broad contact with two ambulacral plates on each side, and the actinostome is covered by four large and six or seven smaller plates. We are forced, therefore, to regard this specimen as a young example of an undescribed species. The test and spines are nearly white, while the peripetalous fasciole is purple.

Station 4913. Southwest of Koshika Islands, Japan, 391 fathoms.

One specimen.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

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REPORTS ON THE SCIENTIFIC RESULTS OF THE EXPEDITION TO THE EASTERN TROPICAL PACIFIC, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," FROM OCTOBER, 1904, TO MARCH, 1905, LIEUT. COMMANDER L. M. GARRETT, U. S. N., COMMANDING.

XI.

DIE XENOPHYOPHOREN.

VON FRANZ EILHARD SCHULZE.

WITH ONE PLATE.

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No. 6. — *Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in charge of* ALEXANDER AGASSIZ, *by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905,* LIEUTENANT COMMANDER L. M. GARRETT, *U. S. N., Commanding.*

XI.

Die Xenophyophoren. Von FRANZ EILHARD SCHULZE.[1]

IM Jahre 1892 hat Goës im Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXIII, Nr. 5, III, p. 195–198 unter der Bezeichnung *Neusina agassizi* einen seiner Ansicht nach neuen Organismus als "a peculiar type of arenaceous Foraminifer from the American tropical Pacific" nach mehreren Exemplaren beschrieben, welche von Alexander Agassiz im Jahre 1890 bei einer seiner Albatross-Expeditionen in der Nähe der Galapagos-Inseln an folgenden drei Stationen erbeutet waren:

Nummer der Albatross-Station.	Position.		Tiefe in Meter.
	Breite.	Länge.	
	° ′	° ′	
3399	1 7 N.	81 4 W.	3097
3414	10 14 N.	96 28 W.	3972
3415	14 46 N.	98 40 W.	3415

Die gewissen Algen, z. B. *Padina pavonia,* äusserlich sehr ähnlichen, blattförmigen Körper von Kinderhand-Grösse und 0,5–2 mm. Dicke zeigen nach Goës "a triangular, fan-like or reniform figure, with more or less strongly arcuate edge. . . . Sometimes the shape is that of a biauriculated leaf, produced much more in breadth than in height. The edge is often undulated in broad folds, and sometimes new individuals sprout

[1] This paper has also been published in the Sitzungsberichte der Gesellschaft naturforschender Freunde, Berlin, 1906, p. 205–229, 1 Taf.

from the broad side, forming irregularly shaped clusters of two or three individuals. The chambers constitute arcuated, concentric, more or less complete bands, increasing in length with age, forming a fan-like growth, commencing with a pointed triangular juvenile stage. . . . The chamber wall is thin, often wrinkled, and here and there pierced by irregularly formed pores of different size. In some places a faint striation running perpendicular to the chamber sutures across the chamber wall can be discovered, probably indicating the divisions into chamberlets. The interstice between the two side walls is crossed by numberless irregular partitions, forming masses of small chambers of different size and form, giving to the structure a sponge-like texture. The color is commonly sooty, with shades in dark olive; when dried, it becomes grayish clay-colored."

Als auffälligsten Charakter bezeichnet aber Goës mit Recht das reichliche Vorkommen netzartig verbundener Bündel von feinen, gelblichen, aus einer chitinartigen Substanz bestehenden, 3–6 μ dicken Fäden, welche ein den ganzen Körper durchsetzendes, feine Sandteilchen und Schalenreste umschliessendes Stroma bilden.

Am Schlusse seines Aufsatzes macht Goës darauf aufmerksam, dass eine von Jullien vor der Küste von Liberia in 4 bis 5 Meter Tiefe gedredgter und von Schlumberger im Jahre 1890 in den Mém. Soc. Zool. de France, Tom. III, p. 211 als *Jullienella foetida* Schlbgr. beschriebener Organismus wahrscheinlich mit seiner *Neusina* nahe verwandt sei, obwohl bei ihm kein aus dünnen Chitinfäden bestehendes Stroma, wohl aber eine mehr einfache und regelmässige Kammerbildung, sowie eigentümliche röhrenförmige Randausläufer vorkommen.

Goës ist geneigt, seine neue Gattung *Neusina* nebst Schlumbergers *Jullienella* als Repräsentanten einer besonderen neuen Foraminiferenfamilie hinzustellen.

Bald nachdem die Arbeit von Goës erschienen war, wies R. Hanitsch in der englischen Zeitschrift "Nature" 1893, Vol. XLVII, p. 365 und 439 darauf hin, dass die von Goës beschriebenen und als Sandforaminiferen gedeuteten (*Neusina agassizi* genannten) Tiefseegebilde schon im Jahre 1889 von Haeckel in seinem Report on the deep sea Keratosa (The Voyage of H. M. S. Challenger, Zoology, Vol. XXXII, p. 62 und 63) unter der Bezeichnung *Stannophyllum zonarium* Hkl. als Tiefsee-Hornspongien ausführlich beschrieben und abgebildet seien.

In gleichem Sinne äusserte sich in demselben Bande Vol. XLVII, p. 390 der "Nature" 1893 F. G. Pearcey, welcher zwar auch von der

völligen Übereinstimmung der *Neusina agassizi* Goës mit Haeckels *Stannophyllum zonarium* überzeugt ist, aber auf Grund einer Prüfung des betreffenden von Haeckel benutzten Challenger-Materiales die Auffassung Haeckels von der Zugehörigkeit des *Stannophyllum* und verwandter Formen (meiner Xenophyophoren) zu den Spongien bestreitet und sie (wie Goës seine *Neusina*) zu den *Sandforaminiferen* stellt.

"In not one species," so sagte er l. c. pag. 390, "could I find the slightest trace of any of the flagellated chambers characteristic of sponges."

Diese Mitteilung von F. G. Pearcey hat dann R. Hanitsch veranlasst, bald darauf in demselben Bande der "Nature" 1893 noch einmal in dieser Sache das Wort zu ergreifen und l. c. pag. 439 darauf hinzuweisen, dass zwar die konzentrischen Linien an den flachen Seiten des blattförmigen *Stannophyllum* mehr dem Wachstumstypus der Foraminiferen als der Spongien entsprächen, dass aber "the chitinous lining in the tube-like body of some Foraminifera certainly bears not the slightest resemblance to the distinct fibrous stroma of *Stannophyllum*, which reminds me much more of the filaments of the true horny sponge *Hircinia*." Auch meinte Hanitsch, dass "the presence of oscula, pores, subdermal cavities, horny skeleton, etc." (auch ohne Nachweis von Geisselkammern) "are sufficient to characterise the form as a sponge," und kam inbezug auf die systematische Stellung der mit *Stannophyllum zonarium* Haeckel identischen *Neusina agassizi* Goës zu folgendem Schluss: "I do not as yet see sufficient reason to differ from Haeckel in regarding it as a sponge, although I have never observed flagellated chambers and cells any more than he."

Ich selbst habe dann im Jahre 1905 in den "Wissensch. Ergebnissen der deutschen Tiefsee- (Valdivia) Expedition, Bd. XI," die Resultate von Untersuchungen mitgeteilt, welche an dem mir damals zugänglichen Materiale der von Haeckel als *Tiefsee-Hornspongien*, von mir aber als eine besondere *Rhizopoden*-Gruppe, "*Xenophyophora*," aufgefassten Organismen angestellt waren.

Das Material zu diesen Studien setzte sich zusammen

1. aus den reichen Schätzen der Challenger-Expedition, welche schon im Jahre 1889 mit Beigabe zahlreicher vortrefflicher Abbildungen von Haeckel im Challenger Report, Zoology, Vol. XXXII, beschrieben, mir jedoch durch das besonders dankenswerte freundliche Entgegenkommen des Direktors des British Museum of nat. hist. grösstenteils zur nochmaligen Untersuchung anvertraut waren;

2. aus den zwar nicht zahlreichen, aber recht gut konservierten Objekten, welche von der ersten deutschen Tiefsee- (Valdivia) Expedition heimgebracht und mir von deren Leiter, Herrn Prof. C. Chun, zur Bearbeitung überlassen waren; sowie

3. aus jenen Xenophyophoren, welche von der Albatross-Expedition der Jahre 1889–90 erbeutet und mir grösstenteils (d. h. mit Ausnahme der von A. Goës studierten Exemplare) von Herrn Prof. Al. Agassiz zur wissenschaftlichen Verwertung geliehen waren.

Als einige für die Auffassung der ganzen Organismengruppe besonders wichtige allgemeine Ergebnisse meiner Untersuchungen führe ich hier folgende auf.

In einem aus Fremdkörpern (Xenophya) *zusammengesetzten lockeren Stützgerüst von verschiedener* (*aber für die einzelnen Gattungen und Arten meist sehr charakteristischer*) *Form findet sich ein System von entweder baumartig verzweigten oder netzförmig verbundenen, hier und da mit Endöffnungen versehenen, dünnwandigen Röhren, welche entweder ein* KERNREICHES PLASMODIUM *oder zahlreiche rundliche Kotballen* (STERKOME) *umschliessen. Während das Plasmodium gewöhnlich viele kleine, glatte, stark lichtbrechende, farblose Körnchen von Baryumsulfat* (*Granellen*) *enthält und nur gelegentlich* (*nach Ausstossen dieser letzteren*) *in einzelne rundliche Zellen* (*Gameten?*) *zerfällt, finden sich zwischen den Sterkomen fast immer gelbliche oder rötliche Konkremente von Eisenoxydhydrat* (*Xanthosome*).

Nach dem vorwiegenden Besitze der GRANELLEN *habe ich die das Plasmodium enthaltenden, meist mehr oder weniger isolierten Röhren als* GRANELLARE, *die mit Sterkomen gefüllten Röhren dagegen als* STERKOMARE *bezeichnet.*

Aus den Endöffnungen der Granellare ragt zuweilen ein hyaliner oder mit Granellen durchsetzter Plasmaklumpen frei hervor.

Bei einer (*systematisch jedenfalls zu sondernden*) *Hauptabteilung der Xenophyophoren, welche ich mit Haeckel nach einer Gattung* Stannoma *Hkl. als eine besondere Familie* Stannomidae, STANNOMIDEN, *bezeichne, tritt zu den Fremdkörpern als ein eigenartiger, vom Organismus selbst produzierter Bestandteil des Stützgerüstes noch ein System zarter, einfacher oder verästelter Fäden, der* LINELLEN, *hinzu, welche sich in Menge zwischen den übrigen Festteilen ausspannen und dem Körper eine mehr filzartige, biegsame Konsistenz verleihen.*

Die andere, dieser Linellen entbehrende Hauptgruppe der Xenophyophoren wird nach der Gattung Psammina *als* Psamminidae, PSAMMINIDEN, *bezeichnet und zeigt wegen der direkten festen Verlötung*

der Xenophya *einen mehr starren und brüchigen Charakter des ganzen Körpers.*

Zur Familie der *Psamminidae* rechnete ich ausser den schon von Haeckel charakterisierten Gattungen *Psammina* Hkl., *Cerelasma* Hkl., *Holopsamma* Carter und *Psammopemma* Marshall noch eine neue Gattung *Psammetta* F. E. Sch., deren damals zunächst einzige Species in der Gestalt so sehr einem menschlichen Blutkörperchen gleicht, dass ich sie *erythrocytomorpha* F. E. Sch. genannt habe. Indem ich beim Studium der feineren Struktur- und Bauverhältnisse der Xenophyophoren von den verhältnismässig gut konservierten Stücken dieser letzteren Spezies, welche die deutsche Tiefsee- (Valdivia) Expedition erbeutet hatte, ausging, gelang es mir, eine befriedigende Einsicht in die Organisationsverhältnisse der ganzen Gruppe zu gewinnen.

Von den *Stannomidae* standen mir Vertreter der drei Gattungen *Stannoma* Hkl., *Stannophyllum* Hkl. und *Stannarium* Hkl. zu Gebote.

Mit diesem, im ganzen aus 2 Familien, 8 Gattungen und 22 Arten bestehenden Materiale konnte ich in den "Wissensch. Ergebn. der ersten deutschen Tiefsee-Expedition" Bd. XI, im Jahre 1905 eine Charakteristik, systematische Übersicht und Bestimmungstabelle aller damals bekannten Xenophyophoren, sowie auch eine tabellarische und kartographische Darstellung ihrer geographischen Verbreitung, also eine Monographie der Xenophyophoren geben.

Seitdem ist mir durch das Entgegenkommen des Leiters der holländischen Siboga-Expedition, des Herrn Prof. Max Weber, noch ein weiteres, aus dem Gebiete des Malayischen Archipels stammendes Xenophyophoren-Material zugegangen, über welches ich vor kurzem in einer eigenen Abhandlung: Die Xenophyophoren der Siboga-Expedition in dem Werke: "Siboga-Expeditie," Vol. IV, bis 1906 ausführlich berichtet habe. Von besonderem Interesse erwies sich dabei eine südlich von Celebes, dicht vor der Mündung der Boni-Bai auf Schlammboden in Menge gefundene, der *Psammetta erythrocytomorpha* F. E. Sch. in Bau und Struktur sehr nahestehende, aber durch ihre rein kugelige Gestalt ausgezeichnete neue Form, welche ich näher untersucht und l. c. als *Psammeta globosa* F. E. Sch. beschrieben habe.

Jetzt ist mir durch die Güte des Herrn Prof. Al. Agassiz noch das Xenophyophoren-Material zur Untersuchung und Beschreibung anvertraut, welches er bei seiner in den Jahren 1904/5 ausgeführten Albatross-Expedition erbeutet hat.

Obwohl diese Kollektion nur schon bekannte Arten enthält, und eine eingehende mikroskopische Untersuchung auch hinsichtlich des feineren Baues dieser merkwürdigen Organismen keine wesentlich neuen Tatsachen ergeben hat, ist sie mir doch wertvoll geworden durch die Gelegenheit zur Prüfung des früher Ermittelten an zahlreichen weiteren Objekten anderer Provenienz und besonders durch die nicht unerhebliche Erweiterung unserer Kenntnis von der geographischen Verbreitung einiger Formen.

Im Ganzen setzt sich dies an Individuen ziemlich reiche Material zusammen aus 5 Arten, welche sämtlich zu den *Stannomiden* gehören, nämlich

Stannoma dendroides Hkl.,
Stannoma coralloides Hkl.,
Stannophyllum zonarium Hkl.,
Stannophyllum globigerinum Hkl., und
Stannophyllum alatum (Hkl.) = (*Stannarium alatum* Hkl.).

Ich bespreche jede einzelne Form für sich und beginne mit

Stannoma dendroides Hkl.

Die Charakteristik, welche Haeckel bei der Aufstellung des Speziesbegriffes *Stannoma dendroides* Hkl. im Jahre 1889 im Challenger Report l. c. p. 72 gegeben hat, bezieht sich vorwiegend auf die äussere Körperform. Sie lautet: "arborescent, irregularly branched (partly dichotomous, partly polychotomous), with slender cylindrical branches tapering towards the conical distal end. Branches free, without anastomoses. The body of the tree-like sponge is 30 to 50 mm. high, 20 to 30 mm. broad, very soft and flexible, in the dry state friable. The short stem, 10 to 20 mm. in height, 3 to 5 mm. in thickness, is either cylindrical or inversely conical, tapering towards the small base, and divided into three to six stout main branches, 3 to 4 mm. in diameter. These divide again into secondary and tertiary branches of varying lengths, between 5 and 20 mm. The branches are slightly curved, and gradually taper from 3 or 2 mm. to 0.5 mm. or less in thickness; the conical end also tapers gradually."

An den feinen, nur 1–3 μ dicken Linellen, welche nicht zu Bündeln vereinigt, sondern mehr isoliert in verschiedener Richtung verlaufen, beobachtete Haeckel keine Verzweigungen. Als Xenophyen fand er vorwiegend Radiolarien-Skelette und Hexactinelliden-Nadeln.

Indem ich in meiner Monographie im Jahre 1905 dieser Schilderung noch einige Züge hinzufügte, hob ich hervor, dass die Verzweigung der

baumartig verästelten Stöckchen, wenn auch nicht ausschliesslich, so doch vorwiegend in ein und derselben Ebene erfolgt, und dass das untere verschmälerte Stielende nicht selten in eine lockere, ganz aus Linellen bestehende Faser-Masse ausläuft.

Obwohl nun das mir jetzt zur Disposition gestellte, grade an *Stannoma dendroides* Hkl. ziemlich reiche Material der Albatross-Expedition 1904/5 zunächst zu einer wesentlichen Abänderung dieser Charakteristik keine Veranlassung bietet, habe ich es doch benutzt, um über einzelne Fragen Aufklärung zu gewinnen, die bisher noch keine befriedigende Lösung erfahren hatten. Dahin gehört z. B. die Vorstellung, welche wir uns von der Art der Befestigung der ganzen Gebilde am Boden zu machen haben. Nach Haeckels oben wörtlich wiedergegebenen Darstellung ist das untere Stielende von *Stannoma dendroides* "either cylindrical or inversely conical tapering towards the small base." Trotzdem zeigt die auf Taf. III in Fig. 1 seiner Abhandlung gegebene Abbildung eines ganzen Stöckchens von *Stannoma dendroides* eine flache basale *Ausbreitung* des unteren Stielendes, welche auf einer annähernd platten festen Unterlage aufsitzt.

Ich selbst hatte früher an den zahlreichen (weit über hundert) Exemplaren von *Stannoma dendroides* Hkl., welche ich in dem Xenophyophoren-Material der Albatross-Expedition von 1899–1900 vorfand, zwar die meisten mit einem einfach konisch-verschmälerten glatten unteren Ende aufhören sehen, jedoch bei manchen Stücken am Stielende die schon mehrfach erwähnte und in meiner Xenophyophoren-Monographie Taf. IV, Fig. 1–3 abgebildete lockere büschelförmige Fasermasse der Linellen gefunden.

Ich nahm damals an, dass alle Stöckchen mit einem solchen Faserschopfe regelmässig an irgend welchen Festkörpern des Bodens angeheftet gewesen seien, und dass, wo ein solcher Schopf fehlt, er nur beim Fange abgerissen wäre.

Als ich jetzt aber die zahlreichen Exemplare der Albatross-Expedition vom Jahre 1904/05 auf die Beschaffenheit ihres unteren Stammendes näher prüfte und dabei auch die mir noch zugängigen Stücke früherer Expeditionen zum Vergleich heranzog, fiel es mir auf, dass in dieser Hinsicht sehr auffällige Unterschiede bestehen. Es zeigte sich nämlich, dass von den über 50 Stücken, welche von der Albatross-Station 4742 — 0° 34′ N.; 117° 15,8′ W. stammen, nur wenige einen basalen Faserschopf besitzen, die meisten vielmehr mit einem *einfachen* glatten konischen oder abgerundeten Stielende aufhören.

Ebenso ist es bei der Mehrzahl aller von der Albatross-Expedition 1899/1900 herrührenden Stücke.

Ein wesentlich anderes Verhalten zeigen dagegen einige Stöckchen der Albatross-Expedition 1904/05, da sie unten nicht mit einer Verschmälerung, sondern im Gegenteil mit einer quer abgestutzten Verbreiterung enden. Diese letztere ist bei zwei Stücken kolbig verdickt, bei einem aber trompetenförmig verbreitert. Die annähernd plane Endfläche weist bei allen dreien kleine Rauhigkeiten auf, als ob sie von einer rauhen Unterlage abgerissen wäre, und ist bei einem Stück noch mit zahlreichen grösseren Foraminiferenschalen besetzt.

Mit einer ähnlichen terminalen Stielverbreiterung muss auch jenes *Stannoma dendroides*-Stöckchen einer festen Unterlage aufgesessen haben, welches Haeckel in seinem Werke: Deep sea Keratosa der Challenger-Expedition l. c. Plate III, Fig. 1 abgebildet hat.

Es hat sich herausgestellt, dass bei der grössten Zahl aller untersuchten Stücke das untere Stielende sich konisch verjüngt und eine glatte oder leicht höckerige Oberfläche hat, während es bei einzelnen Stöckchen in ein lockeres Linellenbüschel ausläuft, bei einigen anderen Exemplaren dagegen sich terminal verdickt und mit einer verbreiterten quer abgestutzten Basalfläche endet.

Dementsprechend wird man wohl annehmen müssen, dass die Mehrzahl der *Stannoma dendroides*-Stöckchen mit ihrem Stiele lose im Sand oder Schlamm stecken, wie etwa eine *Pennatula*, dass andere dagegen entweder mit einem basalen Linellenbüschel an Fremdkörpern des Meeresgrundes angeheftet sind oder mit einer verbreiterten Endfläche des Stieles der nahezu ebenen Oberfläche einer derben (Foraminiferen-) Sandmasse, vielleicht auch einer kompakten festen Unterlage aufsitzen.

Noch ein anderer Umstand ist mir bei einer vergleichenden Durchsicht aller mir jetzt vorliegenden zahlreichen Exemplare von *Stannoma dendroides* Hkl. aufgefallen, dass nämlich die Hauptäste, welche zunächst aus dem einfachen basalen Stiel durch mehr oder minder weitgehende Verzweigung entstehen, keineswegs immer einen kreisrunden Querschnitt zeigen, sondern oft stark *abgeplattet* sind. Diese Abplattung ist dann stets in gleicher Richtung erfolgt, so dass hand- oder fächerförmige Gebilde entstanden sind, deren untere platte Hauptäste sich in ein und derselben Ebene ausbreiten. Nur die letzten Endäste sind drehrund und zwar meist einfach fingerförmig mit geringer Verschmälerung an dem abgerundeten freien Distalende.

Stannoma dendroides Hkl. ist bei der unter Alexander Agassiz in den Jahren 1904/5 ausgeführten Albatross-Expedition an folgenden 4 Stationen erbeutet.

Nummer der Station.	Position.		Tiefe in Meter.	Stückzahl.
	Breite.	Länge.		
	° ′	° ′		
4649	5 17 S.	85 19.5 W.	4090	1
4717	5 10 S.	98 56 W.	3937	1
4721	8 7.5 S.	104 10.5 W.	3814	3
4742	0 3.4 N.	117 15.8 W.	4243	circa 50

Stannoma coralloides Hkl.

In der Gattung *Stannoma* kennen wir neben *St. dendroides* Hkl. noch eine durch die reichlichen Anastomosen ihrer 4–8 mm. langen und nur 2–3 mm. dicken, drehrunden und überall gleich starken Gerüstbalkenstücke ausgezeichnete Spezies von 20–40 mm. Gesamtdurchmesser. Die meist dichotomische Verästelung des Balkensystems erfolgt nicht in ein und derselben Ebene, sondern in verschiedenen Richtungen.

Bei dieser als *Stannoma coralloides* Hkl. bezeichneten, der vorigen im feineren Bau sehr ähnlichen Form fand Haeckel "the fine spongin-fibres much more numerous, larger and more richly developed," und als *Xenophya* fast ausschliesslich Radiolarien.

In den wenigen aus oberen abgerissenen Körperpartien bestehenden Exemplaren, welche mir früher bei Abfassung meiner Monographie allein zu Gebote standen, konnte ich nur sehr zarte Linellen von höchstens 2 μ Durchmesser sehen, während Haeckel bei *St. coralloides* grade die Stärke der Linellen hervorhebt, welche er meistens bis 4 μ, ja sogar gelegentlich 5 bis 10 μ dick fand. Bei den mir jetzt von der Albatross-Expedition 1904/05 vorliegenden Stücken, welche in den unteren Körperregionen etwas besser erhalten sind, finde ich nun zwar (in den untersten Partien) zwischen zahllosen feinen Linellen von 1–2 μ Dicke auch einige dickere (bis zu 4 μ), aber die grosse Mehrzahl ist doch bedeutend dünner als bei *Stannoma dendroides*, wo sie ja durchschnittlich 3–4 μ stark gefunden werden. Ich muss also dabei bleiben, dass für *Stannoma coralloides* die erheblich dünneren Linellen (*St. dendroides* gegenüber) charakteristisch sind.

Von Interesse erscheint mir ferner der Umstand, dass bei einem der neuen Albatross-Exemplare einzelne der untersten, abwärts gerichteten Balken in je ein lockeres Linellenbüschel auslaufen. Auch hier dürfte es sich, ebenso wie bei dem oben erwähnten basalen Linellenschöpfen des Stieles von *Stannoma dendroides*-Bäumchen um eine Einrichtung

zur Befestigung des ganzen Stockes an kleinen festen Körpern des Schlammgrundes handeln.

Wie bei den früher bekannt gewordenen Exemplaren bestehen die *Xenophya* fast ausschliesslich aus Radiolarien.

Die fünf etwa kirschgrossen Exemplare von *Stannoma coralloides*, welche die Albatross-Expedition 1904/05 mitgebracht hat, stammen sämtlich von der Station 4742 — 0° 3.4′ N.; 117° 15.8′ W. — welche in 4243 Meter Bodentiefe einen feinen, von Foraminiferen und Radiolarien durchsetzten Schlick ziegte.

Stannophyllum zonarium Hkl.

Obwohl mir von jenen Gebilden, welche Goës unter der Bezeichnung *Neusina Agassizi* Goës als Foraminiferen beschrieben hat, keine Originalstücke zur Untersuchung zugängig gewesen sind, muss ich sie doch auf Grund seiner eigenen (zu Anfang dieser Abhandlung pag. 206 ausführlich mitgeteilten) Darstellung und den beigegebenen Abbildungen für *Xenophyophoren* halten und wie Hanitsch und Pearcy dem Formenkreis von *Stannophyllum zonarium* Hkl. zurechnen. Gerechtfertigt erscheint dies ausser durch die weitgehende Übereinstimmung der Körperform und des Baues besonders durch das von Goës selbst hervorgehobene reichliche Vorkommen der eigenartigen und für die Xenophyophoren-Familie der *Stannomidae* so überaus charakteristischen Linellen.

Als eine nahe Verwandte der *Neusina* hat Goës ferner (wie schon oben pag. 206 erwähnt wurde) die von Schlumberger zuvor als Foraminifere beschriebene *Jullienella foetida* Schlumberger hingestellt.

Um diesen merkwürdigen Organismus aus eigener Anschauung kennen zu lernen, habe ich mich durch freundliche Vermittelung des Herrn Prof. Raphael Blanchard an den Direktor der geologischen Sammlung der Sorbonne, Herrn Prof. Haug, gewandt, welcher die grosse Güte hatte, mir eines der in seinem Laboratoire in trockenem Zustande aufbewahrten Exemplare von Schlumbergers *Jullienella* nebst einigen Fragmenten zur Untersuchung anzuvertrauen. Ich habe mich davon überzeugt, dass in diesen von Schlumberger vortrefflich beschriebenen und naturgetreu abgebildeten Gebilden *keine* Linellen vorkommen. Auch konnte ich weder in der kompakten harten Schale, noch in den hier und da vorhandenen Inhaltsresten irgend welche Spuren von Sterkomaren oder Granellaren resp. den charakteristischen Granellen auffinden. Dagegen liess sich zwischen den beiden festen Grenzplatten das schon von Schlumberger erkannte System undeutlich geschiedener,

sehr unregelmässiger Hohlräume, wie sie vielen Sandforaminiferen zukommen, leicht nachweisen.

Ich kann daher die *Jullienella* nicht für eine Xenophyophore, sondern muss sie wie der erste Beschreiber für eine *Foraminifere* halten.

Bei der Untersuchung des reichlichen, über 100 Stücke betragenden Materiales von *Stannophyllum zonarium* Hkl. habe ich zunächst die *äussere Gestalt* der bis zu Kinderhand-grossen Exemplare berücksichtigt. Neben der Hauptmasse, welche die schon von Haeckel, Goës und mir früher ausführlich beschriebene und mehrfach abgebildete einfache gestielte Blattform mit einem an beiden Flächen ausgeprägten System konzentrischer, dem freien oberen Konvexrande parallel laufender Furchen zeigt, finden sich zahlreiche Exemplare, welche unter Verlust des Stieles zu einer nieren-, bohnen- oder sichelförmigen Platte geworden sind, wie sie ähnlich von Goës in seiner Fig. 9, von mir in meiner Monographie auf Taf. V, Fig. 2 dargestellt ist. Dabei hängen gewöhnlich von den schmalen Seitenrändern der einzelnen konvexen Bandzonen der Platte ausgefranste Linellenbüschel herab, wie sie auch schon von Goës und mir früher beschrieben und abgebildet sind. Nicht selten erheben sich von der Seitenfläche einer Platte ziemlich rechtwinklig aufsitzende kleine platte Auswüchse von gleicher Beschaffenheit wie die Platte selbst, von mehreren Millimetern Höhe und von sehr verschiedener Gestalt. Einmal sah ich auch an der Seitenfläche eines sonst normalen Exemplares ein anderes gleich grosses und ebenfalls typisches Stück mit einem langen verschmälerten, ziemlich drehrunden und an der Basis etwas verbreiterten Stiele fest aufsitzen.

Dieser letztere Fall scheint mir deshalb wichtig, weil er darauf hindeutet, dass die ganzen Gebilde normaler Weise zunächst wirklich mit der verbreiterten Basis ihres Stieles am Meeresgrunde anderen festen Körpern oder Sandflächen aufsitzen, so wie es Haeckel in seinen Abbildungen dargestellt hat.

Freilich scheint hier grade der Stiel besonders leicht der Degeneration anheimzufallen und zwar zunächst durch Auflockerung und Auffaserung zu einem einfachen Linellenbüschel. Später dürfte er durch Vergrabensein im Sande oder Schlick zur völligen Auflösung und zum Abfallen von dem Körper selbst genötigt werden, ähnlich wie auch die unteren Seitenrandpartien der ganzen Platte. Gut erhaltene Stiele sind bei *Stannophyllum zonarium* nur selten anzutreffen.

Dafür, dass nach dem Zugrundegehen des Stieles der blattförmige Körper gewöhnlich noch mit seinen unteren Seitenrändern im Schlamme steckt, spricht der so häufige Besatz dieser letzteren mit Linellenbüscheln.

Zuweilen aber habe ich auch solche Linellenbüschel aus einer der beiden Seitenflächen der Körperplatte schräge abwärts hervorstehen sehen; was dann darauf hinweisen dürfte, dass hier der ganze Körper mit dieser Seitenfläche auf dem Schlamme oder Sande flach oder schräge aufgelegen hat.

Stannophyllum zonarium Hkl. ist von der Albatross-Expedition 1904/05 an folgenden Stationen erbeutet:

Nummer der Station.	Position.		Tiefe in Meter.	Stückzahl.
	Breite.	Länge.		
	° ′	° ′		
4647	4 33 S.	87 42.5 W.	3667	ca. 40
4649	5 17 S.	85 19.5 W.	4090	ca. 80
4651	5 41 S.	82 59.7 W.	4066	ca. 50
4653	5 47 S.	81 24 W.	980	1
4656	6 54.6 S.	83 34.3 W.	4066	ca. 10
4658	8 29.5 S.	85 35.6 W.	4334	2
4666	11 55 S.	84 20.3 W.	4755	1
4717	5 10 S.	98 56 W.	3937	11
4721	8 7.5 S.	104 10.5 W.	3814	4
4742	0 3.4 N.	117 15 8 W.	4243	ca. 50

Stannophyllum globigerinum Hkl.

Die durch grosse Weichheit und Schlaffheit des ganzen Körpers, sowie durch reichlichen Gehalt an verhältnismässig grossen Foraminiferenschalen ausgezeichnete Spezies *Stannophyllum globigerinum* Hkl. entbehrt des bei *St. zonarium* stark ausgeprägten dichteren Linellenfilzes der beiden planen Grenzflächen.

Während manche Exemplare noch eine Andeutung jener bei *St. zonarium* so deutlich hervortretenden Zonen zeigen, welche durch die dem oberen konvexen Scheibenrande parallel laufenden beiderseitigen Furchen der Scheibe getrennt werden, lässt sich bei anderen davon nichts mehr erkennen. Wo der stets etwas abgeplattete Stiel vorhanden ist, geht er meistens in ein terminales Linellenbüschel aus, seltener endet er quer abgestutzt.

Verwachsungen zweier Stücke, sowie unregelmässig gestaltete leisten- oder plattenförmige Erhebungen auf einer oder beiden Seitenflächen kommen zuweilen vor.

Neben den als *Xenophya* dominierenden Foraminiferen finden sich überall auch zahlreiche Radiolarienskelette, seltener Kieselnadeln oder anderweitige Fremdkörper.

Gefunden ist *Stannophyllum globigerinum* Hkl. an folgenden vier Stationen der Albatross-Expedition 1904/05:

Nummer der Station.	Position.		Tiefe in Meter.	Stückzahl.
	Breite.	Länge.		
	° ′	° ′		
4647	4 33 S.	87 42.5 W.	3667	1
4717	5 10 S.	98 56 W.	3937	1
4721	8 7.5 S.	104 10.5 W.	3814	3
4742	0 3.4 N.	117 15.8 W.	4243	16

Stannophyllum alatum (Hkl.) = **Stannarium alatum** Hkl.

Als Haeckel die Gattung *Stannarium* für solche Stannomiden aufstellte, deren lamellöser Körper seitliche Flügelplatten aufweist, machte er selbst schon auf die enge Verwandtschaft derselben mit *Stannophyllum* aufmerksam, aus welcher sie seiner Ansicht nach durch seitliches Auswachsen neuer Platten entstanden sein dürfte.

Das mir jetzt vorliegende Material der Albatross-Expedition 1904/05 enthält einige Stücke, welche in der äusseren Gestalt zwar ganz mit Haeckels *Stannarium alatum* übereinstimmen, in den meisten übrigen Charakteren aber so wenig von der einfache Blattform aufweisenden Gattung *Stannophyllum* abweichen, dass ich sie in diese letztere vielgestaltige Gattung stellen muss.

Dies dürfte sich um so mehr rechtfertigen, als ja bei einigen *Stannophyllum*-Arten schon gelegentlich geringe leisten- oder plattenförmige Erhebungen an den Seitenflächen des blattförmigen Körpers gefunden sind.

Ob es sich übrigens empfiehlt, den von Haeckel aufgestellten Speziesbegriff als solchen festzuhalten oder die recht verschiedenartigen Stücke, welche diese merkwürdige Flügelbildung zeigen, an schon bestehende *Stannophyllum*-Arten anzuschliessen resp. zu verteilen, kann zweifelhaft erscheinen. Ich ziehe zunächst das erstere vor und halte einstweilen die Ausbildung der grossen senkrechten einfachen oder gelappten *Flügelplatten,* welche zu 3, 4 oder selbst mehreren von einer axialen Fortsetzung des kräftigen Stieles auseinanderweichen, in Verbindung mit der derben lederartigen Konsistenz des ganzen Körpers und dem kräftig entwickelten, an *Stannophyllum zonarium* erinnernden Linellensystem für ausreichend, um einen besonderen Speziesbegriff, *Stannophyllum alatum,* gleichwertig den übrigen von Haeckel innerhalb der Gattung *Stannophyllum* aufgestellten Arten anzunehmen. Hierbei ist freilich festzuhalten, dass sämtliche bisher unterschiedenen *Stannophyllum*-Arten

keine prägnanten und scharfen Unterschiede aufweisen, sondern miteinander durch mannigfache Übergänge verbunden sind, wie schon früher mehrfach von Haeckel und mir hervorgehoben ist.

Übrigens will ich noch betonen, dass bei den Stücken der Albatross-Expedition 1904/05, welche ich zu *Stannophyllum* rechnen muss, entweder eine so deutlich ausgeprägte quere Endabstutzung des kurzen dicken Stieles vorkommt, dass man ein Abreissen von einer ziemlich ebenen Unterlage anzunehmen veranlasst ist, oder dass eine lockere Linellenschopfbildung besteht. In beiden Fällen haften zahlreiche grössere Foraminiferenschalen diesem basalen Stumpf oder Schopf an; was hier umso mehr auffällt, als die *Xenophya* des ganzen übrigen Körpers fast ausschliesslich aus Radiolarienskeletten besteht.

Stannophyllum alatum Hkl. ist von der Albatross-Expedition nur in drei Exemplaren an der *einen* Station 4742 — 0° 3.4′ N.; 117° 15.8′ W. — 4243 m. tief gefunden.

Die folgende Tabelle gibt Auskunft über die sämtlichen Xenophyophoren-Funde der Albatross-Expedition 1904/5.

Von den 146 Fangstationen dieser Expedition, welche mir wegen ausreichender Tiefe des Meeresgrundes (d. h. unter 500 fathoms = 915 m.) überhaupt für Xenophyophoren inbetracht zu kommen scheinen, ergaben demnach 10 Stationen, also ca. 15% solche Rhizopoden. Diese Fundorte liegen sämtlich zwischen dem 12. Grad südlicher und dem ersten Grad nördlicher Breite, sowie zwischen dem 81. Grad und 118. Grad westlicher Länge. Die Bodentiefe beträgt im allgemeinen ca. 4000 m., nur an einer Station (4653) 981 m.

Für alle Fundorte ist *Schlammgrund* notiert.

Hinsichtlich der Häufigkeit der verschiedenen Spezies ist bemerkenswert, dass *Stannophyllum zonarium* Hkl. an allen diesen Fundorten und zwar grösstenteils in reichlicher Menge erbeutet ist. Auch *Stannophyllum globigerinum* Hkl. und *Stannoma dendroides* Hkl. kamen ziemlich häufig vor (an 4 von den 10 Stationen), während *Stannoma coralloides* und *Stannophyllum alatum* sich nur an je einer der betreffenden Stationen fanden.

Da durch die hier mitgeteilten Ergebnisse der Albatross-Expedition 1904/05 und durch die unlängst von mir veröffentlichten Xenophyophoren-Funde der holländischen Siboga-Expeditie (Lieferung IV bis) unsere Kenntnis von der geographischen Verbreitung der Xenophyophoren nicht unerheblich gewonnen hat, und da auch die von Goës bearbeiteten Xenophyophoren-Funde der Albatross-Expedition vom Jahre 1891 in jenen Zusammenstellungen noch keine Aufnahme gefunden hatten, welche ich

Station.	Position. Breite.		Position. Länge.		Tiefe in Meter.	*Stannoma dendroides* Hkl.	*Stannoma coralloides* Hkl.	*Stannophyllum zonarium* Hkl.	*Stannophyllum globigerinum* Hkl.	*Stannophyllum alatum* Hkl.
	° ′		° ′							
4647	4 33	S.	87 42.5	W.	3667	. . . . .	. . . . .	*Stannophyllum zonarium*	*Stannophyllum globigerinum*	
4649	5 17	S.	85 19.5	W.	4090	*Stannoma dendroides*	. . . . .	*Stannophyllum zonarium*		
4651	5 41	S.	82 59.7	W.	4066	. . . . .	. . . . .	*Stannophyllum zonarium*		
4653	5 47	S.	81 24	W.	981	. . . . .	. . . . .	*Stannophyllum zonarium*		
4656	6 54.6	S.	83 34.3	W.	4066	. . . . .	. . . . .	*Stannophyllum zonarium*		
4658	8 29.5	S.	85 35.6	W.	4334	. . . . .	. . . . .	*Stannophyllum zonarium*		
4666	11 55	S.	84 20.3	W.	4755	. . . . .	. . . . .	*Stannophyllum zonarium*		
4717	5 10	S.	98 56	W.	3937	*Stannoma dendroides*	. . . . .	*Stannophyllum zonarium*	*Stannophyllum globigerinum*	
4721	8 7.5	S.	104 10.5	W.	3814	*Stannoma dendroides*	. . . . .	*Stannophyllum zonarium*	*Stannophyllum globigerinum*	
4742	0 3.4	N.	117 15.8	W.	4243	*Stannoma dendroides*	*Stannoma coralloides*	*Stannophyllum zonarium*	*Stannophyllum globigerinum*	*Stannophyllum alatum*

im Jahre 1905 in meiner Monographie der Xenophyophoren gegeben hatte, so lasse ich hier eine Übersicht aller bisher bekannt gewordenen Fundorte von Xenophyophoren folgen, mit Angabe der Bodentiefe und der betreffenden Station der inbetracht kommenden Expeditionen.

I. ATLANTIK.

Position.		Tiefe in Meter.	Expedition Station.
Breite.	Länge.		
° ′	° ′		
38 25 N.	35 50 W.	3065	Chall. 70
22 18 N.	22 2 W.	4392	Chall. 89
37 47 S.	30 20 W.	3138	Chall. 331

II. INDIK.

Position.		Tiefe in Meter.	Expedition Station.
Breite.	Länge.		
° ′	° ′		
1 47.8 S.	41 45.8 O.	1668	Vald. 250
4 50.5 S.	127 59 O.	2081	Siboga 227
5 40.7 S.	120 45.5 O.	1158	Siboga 211
6 12.9 S.	41 17.3 O.	2959	Vald. 240
6 24 S.	124 39 O.	2798	Siboga 221
10 35.6 S.	124 11.7 O.	2050	Siboga 295

III. PAZIFIK.

Position.		Tiefe in Meter.	Expedition Station.
Breite.	Länge.		
° ′	° ′		
35 41 N.	157 42 O.	4209	Chall. 241
35 22 N.	169 53 O.	5307	Chall. 244
14 46 N.	98 40 W.	3344	Alb. 3415
10 14 N.	96 28 W.	3972	Alb. 3414
2 56 N.	134 11 O.	3660	Chall. 216 A.
2 55 N.	124 53 W.	3935	Chall. 198
1 7 N.	8 4 W.	3097	Alb. 3399
0 50 N.	137 54 W.	4507	Alb. 3684 (17[1])
0 3.4 N.	117 15.8 W.	4243	Alb. 4742
0 33 S.	151 34 W.	4438	Chall. 271

[1] In meiner Monographie (im Jahre 1905) als Albatross-Station 17 aufgeführt.

III. PAZIFIC, *Continued.*

Position.						Tiefe in Meter.	Expedition Station.
Breite.			Länge.				
°	′		°	′			
0	42	S.	147	0	O.	2013	Chall. 220
2	34	S.	149	9	W.	5353	Chall. 270
3	48	S.	152	56	W.	4758	Chall. 272
4	33	S.	87	42.5	W.	3667	Alb. 4647
5	10	S.	98	56	W.	3937	Alb. 4717
5	17	S.	85	19.5	W.	4090	Alb. 4649
5	41	S.	82	59.7	W.	4066	Alb. 4651
5	47	S.	81	24	W.	981	Alb. 4653
6	54.6	S.	83	34.3	W.	4066	Alb. 4656
7	25	S.	152	15	W.	5033	Chall. 274
8	7.5	S.	104	10.5	W.	3814	Alb. 4721
8	29.5	S.	85	35.6	W.	4334	Alb. 4658
11	55	S.	84	20.3	W.	4755	Alb. 4666
39	22	S.	98	46	W.	4154	Chall. 294

Von den 33 jetzt bekannten Fundorten gehören demnach 3 dem Gebiete des *atlantischen*, 6 dem des *indischen* und 24 dem des *stillen* Ozeans an.

Sämtliche Fundorte liegen zwischen 40° nördlicher und 40° südlicher Breite. Die meisten finden sich in der Nähe des Äquators, d. h. zwischen 10° nördlicher und 10° südlicher Breite. Nur ganz wenige liegen ausserhalb der Tropen, nämlich drei nördlich vom nördlichen und zwei südlich vom südlichen Wendekreis.

Auf der hier folgenden kleinen Karte werden diese Verhältnisse zu unmittelbarer Anschauung gebracht durch die roten Zeichen, bei welchen durch die Zahl der Zacken die Anzahl der an ein und demselben Orte gefundenen Spezies angegeben ist, während ein kreisrunder Fleck den Ort bezeichnet, wo nur *eine* Spezies erhalten ist.

Eine Anordnung der 33 Fundorte nach der Bodentiefe ergibt folgende Tabelle:

BATHYMETRISCHE VERBREITUNG DER XENOPHYOPHOREN.

Tiefe in Meter.	Expedition Station.	Position.						Spezies.
		Breite.			Länge.			
		°	′		°	′		
981	Albatros 4653	5	47	S.	81	24	W.	*Stannophyllum zonarium* Hkl.
1158	Siboga 211 . .	5	40.7	S.	120	45.5	O.	*Psammetta globosa* F. E. Sch., *Psammina globigerina* Hkl., *Stannophyllum globigerinum* Hkl.

BATHYMETRISCHE VERBREITUNG DER XENOPHYOPHOREN.

Continued.

Tiefe in Meter.	Expedition Station.	Position.		Spezies.
		Breite.	Länge.	
		° ′	° ′	
1668	Valdivia 250 .	1 47.8 S.	41 58.8 O.	*Psammetta erythrocytomorpha* F. E. Sch.
2013	Challenger 220	0 42 S.	147 0 O.	*Psammina globigerina* Hkl.
2050	Sib. 295 . . .	10 35.6 S.	124 11.7 O.	*Psammophyllum globigerinum* Hkl.
2081	Sib. 227 . . .	4 50.5 S.	127 59 O.	*Psammina globigerina* Hkl.
2798	Sib. 221 . . .	6 24 S.	124 39 O.	*Stannophyllum globigerinum* Hkl.
2959	Vald. 240 . .	6 12.9 S.	41 17.3 O.	*Stannophyllum globigerinum* Hkl.
3065	Chall. 70 . .	38 25 N.	35 50 W.	*Holopsamma cretaceum* Hkl.
3097	Alb. 3399 . .	1 7 N.	8 4 W.	*Stannophyllum zonarium* Hkl.
3138	Chall. 331 . .	37 47 S.	30 20 W.	*Psammina plakina* Hkl.
3344	Alb. 3415 . .	14 46 N.	98 40 W.	*Stannophyllum zonarium* Hkl.
3660	Chall. 216 A .	2 56 N.	134 11 O.	*Cerellasma lamellosa* Hkl.
3667	Alb. 4647 . .	4 33 S.	87 42.5 W.	*Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl.
3814	Alb. 4721 . .	8 7.5 S.	104 10.5 W.	*Stannoma dendroides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl.
3935	Chall. 198 . .	2 55 N.	124 53 W.	*Stannophyllum reticulatum* Hkl.
3937	Alb. 4717 . .	5 10 S.	98 56 W.	*Stannoma dendroides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl.
3972	Alb. 3414 . .	10 14 N.	96 28 W.	*Stannophyllum zonarium* Hkl.
4066	Alb. 4651 . .	5 41 S.	82 59.7 W.	*Stannophyllum zonarium* Hkl.
4066	Alb. 4656 . .	6 54.6 S.	83 34.3 W.	*Stannophyllum zonarium* Hkl.
4090	Alb. 4649 . .	5 17 S.	85 19.5 W.	*Stannoma dendroides* Hkl., *Stannophyllum zonarium* Hkl.
4154	Chall. 294 . .	39 22 S.	98 46 W.	*Holopsamma argillaceum* Hkl.
4209	Chall. 241 . .	35 41 N.	157 42 O.	*Stannophyllum flustraceum* Hkl.
4243	Alb. 4742 . .	0 3.4 N.	117 15.8 W.	*Stannoma dendroides* Hkl., *Stannoma coralloides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl., *Stannophyllum alatum* Hkl.
4334	Alb. 4658 . .	8 29.5 S.	85 35.6 W.	*Stannophyllum zonarium* Hkl.
4892	Chall. 89 . .	22 18 N.	22 2 W.	*Psammopemma calcareum* Hkl.
4438	Chall. 271 . .	0 33 S.	151 34 W.	*Cerelasma gyrosphaera* Hkl., *Stannoma dendroides* Hkl., *Stannoma coralloides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum radiolarium* Hkl., *Stannophyllum pertusum* Hkl., *Stannophyllum venosum* Hkl., *Stannophyllum globigerinum* Hkl.
4507	Alb. 3684 (17[1])	0 50 N.	137 54 W.	*Stannoma dendroides* Hkl., *Stannoma coralloides* Hkl., *Stannophyllum zonarium* Hkl., *Stannophyllum globigerinum* Hkl.
4755	Alb. 4666 . .	11 55 S.	84 20.3 W.	*Stannophyllum zonarium* Hkl.
4758	Chall. 272 . .	3 48 S.	152 56 W.	*Psammopemma radiolarium* Hkl., *Stannoma dendroides* Hkl., *Stannophyllum alatum* Hkl.
5033	Chall. 274 . .	7 25 S.	152 15 W.	*Psammina nummulina* Hkl.
5307	Chall. 244 . .	35 22 N.	169 53 O.	*Stannophyllum annectens* Hkl.
5353	Chall. 270 . .	2 34 S.	149 9 W.	*Stannarium concretum* Hkl.

[1] In meiner Monographie (im Jahre 1905) als Albatross-Station 17 aufgeführt.

Man sieht, dass von den 33 bekannten Fundorten 27, also fast 82%, zwischen 2000 und 5000 m. Tiefe haben und dass von diesen wieder 12 Fundstellen, also nahezu 34% der ganzen Reihe, zwischen 4000 und 5000 m. tief sind.

Nur 3 Fundorte bleiben oberhalb 2000 m., und von diesen erreicht eine sogar (mit 981 m.) noch nicht einmal 1000 m.

Von den drei unter 5000 m. tiefen Fundorten geht der tiefste bis zu 5353 m. hinab.

Ein Einfluss der Bodentiefe auf die Verbreitung der einzelnen systematischen Gruppen lässt sich nicht erkennen. Weder die beiden Familien der Psamminiden und Stannomiden, noch die einzelnen Gattungen zeigen eine deutliche Abhängigkeit ihres Vorkommens von der Bodentiefe. Höchstens könnte man hervorheben, dass die Gattung *Psammetta* bisher nur oberhalb 2000 m. gefunden ist.

Einzelne Spezies, wie z. B. *Stannophyllum zonarium* Hkl., kommen in sehr verschiedenen Tiefen vor — von 981 bis 4755 m.

Zum Schluss gebe ich eine nach dem Zoolog. System geordnete Übersicht der Fundorte aller bisher bekannt gewordenen Xenophyophoren-Spezies.

Es sind also bisher die Stannomiden in weiterer Verbreitung gefunden als die Psamminiden und speziell einige Arten, wie *Stannoma dendroides* Hkl., *Stannophyllum zonarium* Hkl., und *Stannophyllum globigerinum* Hkl., besonders reichlich im östlichen Teile des tropischen Pazifik.

Die Psamminiden scheinen mehr dem Indischen Ozean und speziell dem Gebiete der Sunda-Inseln anzugehören.

NACH DEM SYSTEM GEORDNET.

	Expedition Station.	Position.		Tiefe in Meter.
		Breite.	Länge.	
A. Psamminidae F. E. Sch.				
I. *Psammetta* F. E. Sch.		° ′	° ′	
1. *Ps. globosa* F. E. Sch.	Siboga 211 . .	5 40.7 S.	120 45.5 O.	1158
2. *Ps. erythrocytomorpha* F. E. Sch.	Valdivia 250 .	1 47.8 S.	41 58.8 O.	1668
II. *Psammina* Hkl.				
1. *Ps. plakina* Hkl. . .	Chall. 331 . .	37 47.0 S.	30 20.0 W.	3138
2. *Ps. globigerina* Hkl. .	Chall. 220 . .	0 42.0 S.	147 0.0 O.	2013
	Siboga 211 . .	5 40.7 S.	120 45.5 O.	1158
	Siboga 227 . .	4 50.5 S.	127 59.0 O.	2081
3. *Ps. nummulina* Hkl. .	Chall. 274 . .	7 25.0 S.	152 15.0 W.	5033
III. *Cerelasma* Hkl.				
1. *C. gyrosphaera* Hkl. .	Chall. 271 . .	0 33.0 S.	151 34.0 W.	4438
2. *C. lamellosa* Hkl. . .	Chall. 216 A .	2 56.0 N.	134 11.0 O.	3660

NACH DEM SYSTEM GEORDNET, *Continued.*

	Expedition Station.	Position.		Tiefe in Meter.
		Breite.	Länge.	
IV. *Holopsamma* Carter		° ′	° ′	
1. *H. cretaceum* Hkl. .	Chall. 70. . .	38 25.0 N.	35 50.0 W.	3065
2. *H. argillaceum* Hkl. .	Chall. 294 . .	39 22.0 S.	98 46.0 W.	4154
V. *Psammopemma* Marshall				
1. *Ps. radiolarium* Hkl. .	Chall. 272 . .	3 48.0 S.	152 56.0 W.	4758
2. *Ps. calcareum* Hkl . .	Chall. 89 . .	22 18.0 N.	22 2.0 W.	4392
B. **Stannomidae** F. E. Sch.				
I. *Stannoma* Hkl.				
1. *St. dendroides* Hkl. .	Chall. 271 . .	0 33.0 S.	151 34.0 W.	4438
	Chall. 272 . .	3 48.0 S.	152 56.0 W.	4758
	Alb. 3684 (17 [1])	0 50.0 N.	137 54.0 W.	4507
	Alb. 4649 . .	5 17.0 S.	85 19.5 W.	4090
	Alb. 4717 . .	5 10.0 S.	98 56.0 W.	3937
	Alb. 4721 . .	8 7.5 S.	104 10.5 W.	3814
	Alb. 4742 . .	0 3.4 N.	117 15.8 W.	4243
2. *St. coralloides* Hkl. .	Chall. 271 . .	0 33.0 S.	151 34.0 W.	4438
	Chall. 272 . .	3 48.0 S.	152 56.0 W.	4758
	Alb. 3684 (17 [1])	0 50.0 N.	137 54.0 W.	4507
	Alb. 4742 . .	0 3.4 N.	117 15.8 W.	4243
II. *Stannophyllum* Hkl.				
1. *St. zonarium* Hkl. . .	Chall. 271 . .	0 33.0 S.	151 34.0 W.	4438
	Alb. 3299 . .	1 7.0 N.	81 4.0 W.	3097
	Alb. 3414 . .	10 14.0 N.	96 28.0 W.	3972
	Alb. 3415 . .	14 46.0 N.	98 40.0 W.	3415
	Alb. 3684 (17 [1])	0 50.0 N.	137 54.0 W.	4507
	Alb. 4647 . .	4 33.0 S.	87 42.5 W.	3667
	Alb. 4649 . .	5 17.0 S.	85 19.5 W.	4090
	Alb. 4651 . .	5 41.0 S.	82 59.7 W.	4066
	Alb. 4653 . .	5 47.0 S.	81 24.0 W.	981
	Alb. 4656 . .	6 54.6 S.	83 34.3 W.	4066
	Alb. 4658 . .	8 29.5 S.	85 35 6 W.	4334
	Alb. 4666 . .	11 55.0 S.	84 20.3 W.	4755
	Alb. 4717 . .	5 10.0 S.	98 56.0 W.	3937
	Alb. 4721 . .	8 7.5 S.	104 10.5 W.	3814
	Alb. 4742 . .	0 3.4 N.	117 15.8 W.	4243
2. *St. radiolarium* Hkl. .	Chall. 271 . .	0 33.0 S.	151 34.0 W.	4438
3. *St. pertusum* Hkl. . .	Chall. 271 . .	0 33.0 S.	151 34.0 W.	4438
4. *St. venosum* Hkl. . .	Chall. 271 . .	0 33.0 S.	151 34.0 W.	4438
5. *St. globigerinum* Hkl. .	Chall. 271 . .	0 33.0 S.	151 34.0 W.	4438
	Alb. 3684 (17 [1])	0 50.0 N.	137 54 0 W.	4507
	Valdivia 240 .	6 12.9 S.	41 17.3 O.	2959
	Siboga 211 . .	5 40.7 S.	120 45.5 O.	1158
	Siboga 221 . .	6 24.0 S.	124 39.0 O.	2798
	Siboga 295 . .	10 35.6 S.	124 11.7 O.	2050
	Alb. 4647 . .	4 33.0 S.	87 42.5 W.	3667
	Alb. 4717 . .	5 10.0 S.	98 56.0 W.	3937
	Alb. 4721 . .	8 7.5 S.	104 10.5 W.	3814
	Alb 4742 . .	0 3.4 N.	117 15.8 W.	4243
6. *St. reticulatum* Hkl. . .	Chall. 198 . .	2 55.0 N.	124 53.0 W.	3935
7. *St. flustraceum* Hkl. .	Chall. 241 . .	35 41.0 N.	157 42.0 O.	4209
8. *St. annectens* Hkl. . .	Chall. 244 . .	35 22.0 N.	169 53 0 O.	5307
9. *St. alatum* Hkl. . . .	Chall. 272 . .	3 48.0 S.	152 56.0 W.	4758
	Alb. 4742 . .	0 3.4 N.	117 15.8 W.	4243
III. *Stannarium* Hkl.				
St. concretum Hkl. . . .	Chall. 270 . .	2 34.0 S.	149 9.0 W.	5353

[1] In meiner Monographie (im Jahre 1905) als Albatross-Station 17 aufgeführt.

TAFEL.

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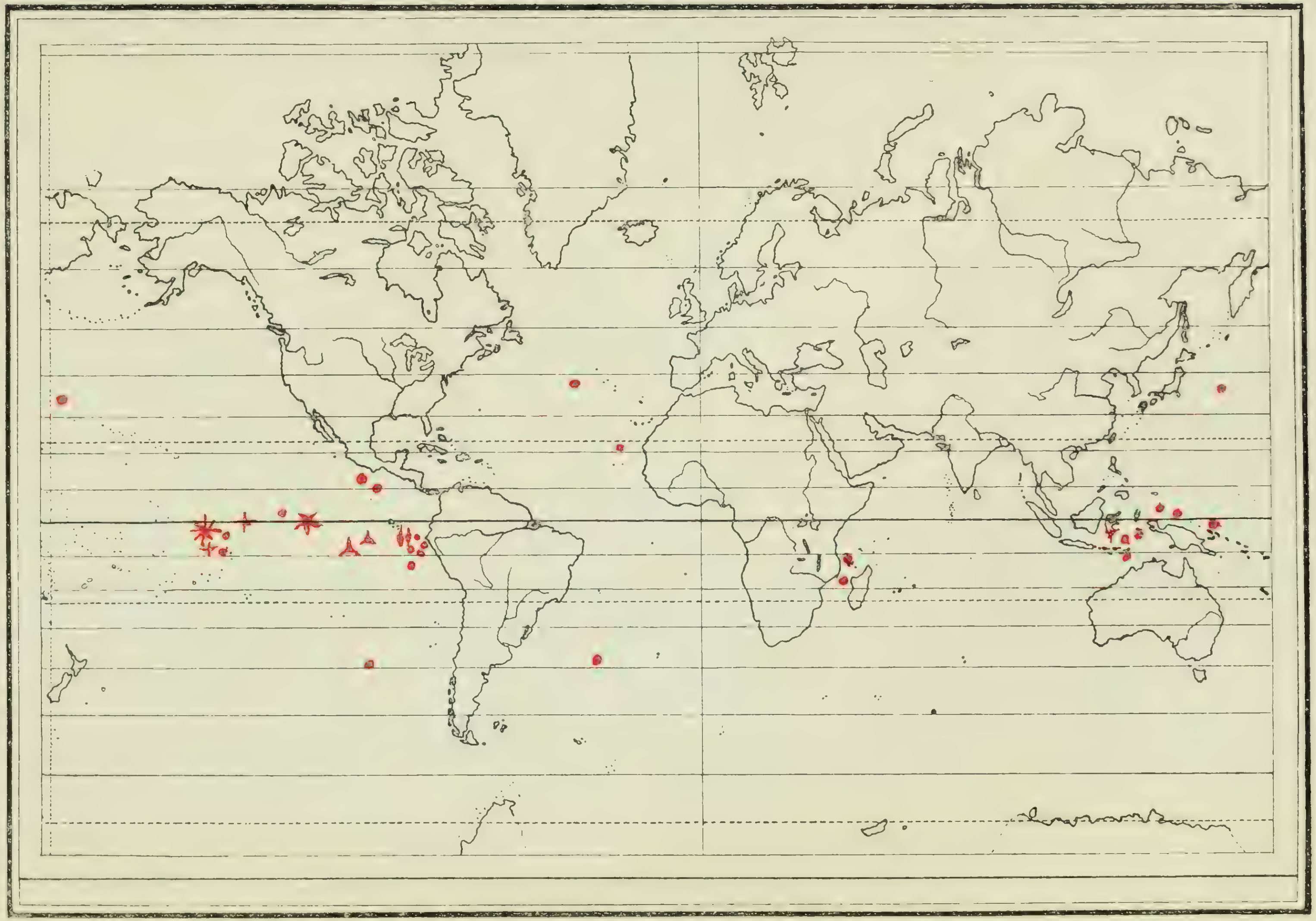

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THE CIDARIDAE.

By Hubert Lyman Clark.

With Eleven Plates.

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No. 7. — *The Cidaridae.* By Hubert Lyman Clark.

Introduction.

The opening years of the present century have witnessed the publication of an unusual number of quarto volumes dealing with the morphology and classification of the Echini. In each of these the Cidaridae receive considerable attention, and many genera of that family, new either in name or in contents, are proposed. As the different writers reveal wide divergence of opinion as to the relative importance of the characters on which the classification of the Echini is based, the arrangement of the Cidaridae differs to an unusual degree in these several reports. Mortensen (:**03**)[1] practically rejects previous classifications and the principles on which they are based, and, ignoring the fossil forms, to which his method is not applicable, recognizes thirteen genera and a subgenus, defined wholly in terms of the pedicellariae, the spicules of the pedicels, and occasionally the spines. It is only fair to state, however, that the writer says frankly, these features are not "sufficient for definitive diagnoses." He includes in his classification 42 species, and lists 12 others which he is unable to place satisfactorily because of lack of information about the pedicellariae. Very soon after this volume appeared, de Meijere's (:**04**)[2] valuable report on the "Siboga" Echini was published. Unwilling to accept Mortensen's genera unreservedly, the writer adopts the clumsy and unsatisfactory method of recognizing only a single genus, Cidaris, and using Mortensen's names for subgenera. Later in the same year Agassiz (:**04**)[3] in his report on the Panamic deep-sea Echini, points out the weaknesses of Mortensen's method and the unsatisfactory nature of his results, and emphasizes anew the great morphological significance of the test (including the abactinal system). Two years

[1] The Danish Ingolf-Expedition, **4**, 1. Echinoidea. Part 1. Th. Mortensen. Translated by Torben Lundbeck. 193 pp., 21 pls. Copenhagen, 1903.

[2] Die Echinoidea der Siboga-Expedition. J. C. H. de Meijere. 252 pp., 23 pls. Leiden, 1904.

[3] The Panamic Deep Sea Echini. Alexander Agassiz. Mem. Mus. Comp. Zoöl., **31**, 243 pp., 112 pls. 1904.

later Döderlein (:06),[1] in an effort to avoid some of the difficulties of Mortensen's system, and yet to retain the valuable results of his work, offers a classification of the recent Cidaridae, consisting of ten genera and five subgenera, defined chiefly in terms of the pedicellariae. This classification, however, is quite different from any of its predecessors because, while Döderlein attempts to apply rigidly the recent International Code of zoölogical nomenclature, his interpretation of certain perplexing cases is quite different from either Mortensen's or Agassiz's. Finally Agassiz and Clark (:07)[2] reject the proposed innovations of both Mortensen and Döderlein and offer considerable evidence in support of their view that the pedicellariae of the Cidaridae are as unreliable for generic characters as are the spines.

It is perfectly obvious, therefore, that the classification of the Cidaridae is at the present time in a state of great confusion, and that some effort should be made to reduce it to order and place it on a permanent basis. Thanks to the great kindness of Mr. Agassiz, a very unusual amount of material, both recent and fossil, has been accessible to me during the past two years, and I have endeavored to find and formulate a natural arrangement of the Cidaridae. Needless to say, Mr. Agassiz is not responsible in any way for statements made or opinions expressed in the following pages, but whatever value my results may have are due to his constant sympathy and encouragement, and I wish here, in this inadequate way, to express my thanks to him. I have also to thank Dr. Richard Rathbun for the privilege of examining the collection of Cidaridae in the United States National Museum, and this proved to be of added interest because it has recently been studied by Dr. Mortensen, who, in many cases, left labels in his own hand, showing the views he held as to the identification of the specimens. As my point of view differs fundamentally from his, I desire to do him full justice, and the examination of a collection, a large part of which has been named by him, was therefore of special importance to me. Finally I may add that in the preparation of this report I have personally handled not less than 3,100 specimens, representing 48 of the 60 recent species which appear to me to be valid, and all of the 15 recent genera herein recognized.

[1] Die Echinoiden der deutschen Tiefsee-Expedition. Ludwig Döderlein. 290 pp., 42 pls. Jena, 1906.

[2] Hawaiian and other Pacific Echini. The Cidaridae. Alexander Agassiz and Hubert Lyman Clark. Mem. Mus. Comp. Zoöl., 34, 42 pp., 44 pls. 1907.

Historical summary.

The first writer to use the name Cidaris for a genus of Echini was Klein (**1734**), who, however, included all of the regular sea-urchins under that name. Linné (**1758**) used the same name for a *species* of Echinus, but Leske (**1778**) was the first writer subsequent to Klein who recognized Cidaris as a genus. Only one of the 28 species which he includes in the genus belongs in the family Cidaridae as understood to-day, and to that one he gave the name *papillata.* Now it is clear from both text and figures that Leske intended to include under the name "*Cidaris papillata*" all those regular Echini with the conspicuous interambulacral tubercles of the Cidaridae. His "species" is therefore a composite group, including not only the now well-known European *Dorocidaris papillata*, but also *Phyllacanthus imperialis* and several species of the restricted genus Cidaris, one of which appears to have been *tribuloides* Lamarck. The next writer to deal with the classification of the Echini was Lamarck (**'16**), and he clearly indicates and defines the group which we now call the Cidaridae. He called them "Turbans," under his genus Cidarites. So far as the Cidaridae are concerned the name Cidarites is equivalent to Leske's *Cidaris papillata* and is obviously a synonym of Cidaris. It cannot be used, therefore, at the present time for any genus of animals. Lamarck listed eleven species of "Turbans," all but one of which were recognized and described by Alexander Agassiz in 1872, in his classic "Revision of the Echini." No attempt to subdivide the genus Cidaris was made until 1835, when Brandt established the genus Phyllacanthus for a supposedly new species, *dubia.* He divided Lamarck's Cidarites into two sections, A (including the species not in B and for which he selected and named *tribuloides* Lam. as the type species) and B, Phyllacanthus, with *dubia* for the type, and including also *imperialis*, *hystrix*, *geranioides*, and *pistillaris.* Later investigation made it plain that of these four only *imperialis* and *pistillaris* are congeneric with *dubia*, and the other two were therefore returned to Cidaris. In 1872 A. Agassiz showed, however, that Lamarck's *baculosa*, *verticillata*, and *annulifera* had important features in common with *dubia* and *imperialis* and accordingly placed them in Phyllacanthus. When Agassiz and Desor (**'46**) considered the Cidaridae, they neglected Phyllacanthus, but established Goniocidaris with *geranioides* for the type, and with it associated a "new" species *quoyi*, which subsequently proved to be synonymous with Lamarck's *tubaria.* In 1854 Desor suggested as genera of fossil Cidaridae, Rhabdocidaris, Diplocidaris, Porocidaris, and Leiocidaris, and in

1858 he described the fossil Eocidaris. The same year (1858) Quenstedt named Polycidaris and Leptocidaris for fossil forms. In 1862 Cotteau described the remarkable fossil Orthocidaris, and the following year the equally interesting fossil Temnocidaris. In 1863, A. Agassiz suggested the name Stephanocidaris for Lamarck's *bispinosa*, and Prionocidaris for *pistillaris*. At the same time he proposed Chondrocidaris as a new genus for a notable species from the Hawaiian Islands, and Gymnocidaris for *metularia* Lam. and a supposedly new species, *minor*. He also proposed Orthocidaris and Temnocidaris as new genera of recent Cidaridae, but later (1869) withdrew them as preoccupied by Cotteau's fossil forms. At this later date he suggested Dorocidaris for a new species, *abyssicola*, associating with it *affinis* Phil. and *papillata* Leske. With the last Lamarck's *hystrix* is synonymous, and consequently, as a result of these various changes, there remained in Lamarck's genus "Cidarites: Turbans" only the well-known West Indian species, *tribuloides*.

In the "Revision of the Echini" (1872) A. Agassiz recognized only six genera of the recent Cidaridae, as follows: —

Cidaris Klein, with 3 species. (Including Gymnocidaris A. Ag.)
Dorocidaris A. Agassiz, with 1 species. (Including Orthocidaris A. Ag.)
Phyllacanthus Brandt, with 6 species. (Including Prionocidaris A. Ag., and Chondrocidaris A. Ag.)
Stephanocidaris A. Agassiz, with 1 species.
Porocidaris Desor, with 1 species.
Goniocidaris Desor, with 3 species. (Including Temnocidaris A. Ag.)

This classification has been maintained by Agassiz ever since, without any changes other than the addition of ten more species (1881, 1883, 1898) and the unique genus Centrocidaris (1904).

In 1877 Studer described Schleinitzia as a recent genus allied to Phyllacanthus. In 1883 Pomel divided the "Cidaridés" into three subfamilies, the Cidariens, Goniocidariens, and Rhabdocidariens. The first contains four genera, including of Agassiz's six only Cidaris, which is divided into five sections (subgenera?); the second subfamily contains four genera also, including Dorocidaris and Goniocidaris of Agassiz's list; the third contains seven genera, including the remaining three of Agassiz, though Stephanocidaris is considered only a subgenus (?) of Phyllacanthus. Although Pomel thus recognizes fifteen genera and six subgenera (?), his classification of the recent forms is essentially identical with that of A. Agassiz. The new genera which he proposes are Tylocidaris, Stereocidaris, Typocidaris, and Pleurocidaris, all for fossil

forms. His proposed subgenera of Cidaris are, Plegiocidaris, Paracidaris, Procidaris, Polycidaris, and Eucidaris. In 1884 Zittel proposed Anaulocidaris for a fossil cidaroid, and in 1885 Döderlein used the name Discocidaris for some recent Japanese species. In 1887 Döderlein published a classification of the Cidaridae, including the fossil as well as the recent forms. Of the 22 genera which he recognizes, 15 include only fossil species. He rejects Stephanocidaris altogether, and uses Desor's name Leiocidaris for Phyllacanthus. For some inexplicable reason he considers *Porocidaris sharreri* A. Ag. as a living representative of Pomel's genus Pleurocidaris. To another of Pomel's genera, Stereocidaris, he assigns three recent Japanese species which he describes. He proposes four new genera of fossil cidaroids, but only gives names to three: Mikrocidaris, Triadocidaris, and Miocidaris. In 1889 Duncan's "Revision of the Genera . . . of the Echinoidea" appeared, with a classification of the Cidaridae, which at first sight seems unique, but on examination proves to be novel only in the rank assigned to the different groups. The writer divides the family into two sections, of which the first contains four genera and one subgenus, and the second contains two genera. For recent forms only the genus Cidaris, with a subgenus Goniocidaris, is allowed, but the heterogeneous nature of such a genus is so far acknowledged that it is divided into seven "divisions," of which five contain the recent species. These five "divisions" with the subgenus Goniocidaris correspond in name and contents to the genera maintained by A. Agassiz. In 1902 Lambert proposed for certain fossil and recent Cidaridae previously referred to Stereocidaris, the name Phalacrocidaris, and in 1903 he suggested for some fossil species allied to Phyllacanthus, the name Aulacocidaris.

In 1903 Mortensen entirely rearranged the recent species of the family, uniting or separating them according to resemblances or differences in the large globiferous pedicellariae. In this way he makes thirteen genera and a subgenus, and although he uses the names of the six genera of A. Agassiz, the grouping of the species is wholly different from that writer's. Mortensen's classification is as follows: —

Dorocidaris A. Ag. (emend.), 4 species.
Tretocidaris, g. n., 3 species.
Stephanocidaris A. Ag. (emend.), 3 species.
Schizocidaris, g. n., 1 species.
Cidaris Klein (emend.), 8 species.
Chondrocidaris A. Ag., 1 species.
Acanthocidaris, g. n., 1 species.

Stereocidaris Pomel, 10 species.
Goniocidaris Desor, 4 species and subgenus Discocidaris Döderlein, 3 species.
Petalocidaris, g. n., 1 species.
Phyllacanthus Brandt (emend.), 3 species.
Histocidaris, g. n., 1 species.
Porocidaris Desor, 1 species and 1 variety.
Genus undetermined, 12 species.
Total, 56 species and 1 variety.

Of these 56 species, seven, and the one variety, are described for the first time, but only one of them is figured. Unfortunately Mortensen was handicapped by lack of material and the apparent necessity of not denuding even in part the specimens which were available, and as a consequence his descriptions are, with one exception, incomplete, and in several cases quite inadequate. Good photographs of his types would be a very great help in recognizing these supposedly new species.

In 1906 Döderlein presents his classification of the recent Cidaridae, the result of more than twenty years' study of the family. It is radically different from his earlier (1887) arrangement, not merely because no reference is made to fossil forms, but because he endeavors to make use of Mortensen's principles, which his own observations often contradict[1] and his judgment not infrequently condemns.[2] This latest arrangement of the family is as follows : —

Cidaris Leske (syn. Dorocidaris A. Ag.), 4 species.
Tretocidaris Mortensen, 3 species.
Cidarites Lamarck (syn. Cidaris emend. Mortensen).
  Subgenus Dorocidaris A. Ag., 4 species.
    Gymnocidaris A. Ag., 3 species and 1 variety.
    Stephanocidaris A. Ag., 5 species and 7 varieties.
Chondrocidaris A. Ag., 1 species.
Goniocidaris L. Agassiz et Desor.
  Subgenus Goniocidaris s. str., 6 species.
    Discocidaris Död., 6 species.
Stereocidaris Pomel, 14 species.
Acanthocidaris Mortensen, 1 species.
Phyllacanthus Brandt, 1 species and 3 varieties.
Histocidaris Mortensen, 2 species.
Porocidaris Desor, 1 species and 1 variety.
Genus undetermined, 6 species.
Total: 10 genera, 5 subgenera, 57 species, and 12 varieties.

[1] Compare page 102, line 24, with page 106, lines 34–36 and page 109, lines 20–21.
[2] See p. 93 *et seq.*

In 1907 A. Agassiz and Clark published descriptions and numerous figures of nine new species of Cidaridae and instituted two new genera, Anomocidaris and Aporocidaris. They also furnished much additional information concerning Stephanocidaris, Centrocidaris, and Acanthocidaris and in regard to diversity of form in the pedicellariae of the group.

Fundamental Principles for a Natural Classification.

Before attempting to set forth a revised classification of the Cidaridae, if it is hoped to have it stable and generally acceptable, one ought to make plain the principles on which it is based. These principles must take into account not only the characters afforded by the specimens themselves and the proper estimation of the relative value of these, but also the selection of names for the genera and species held to be valid. Fortunately there is coming to be more and more general agreement among zoölogists as to the principles which should govern in the selection of names, and the very general acceptance of the International Code of Nomenclature, at least in its essentials, indicates clearly the approach of the time when nomenclature will be fixed. In the following pages adherence has been given to the rules of the International Code, but whenever there has been room for difference of opinion as to the application of those rules, that course has been followed which would cause the least possible change from currently accepted names. Consequently there are few changes from the names established or indorsed by A. Agassiz in the "Revision of the Echini" and almost universally used in the last quarter of the nineteenth century. Unfortunately there is no code by which can be determined the relative importance of the various characters which distinguish the different species and genera of Echini. Here each writer is thrown upon his own resources, and his proposed classification will stand or fall according to the judgment he displays in selecting stable and significant characters. The fundamental difficulty with the classification of Mortensen is that it is based almost wholly upon the characters of the pedicellariae alone, and the history of zoölogy shows again and again that a classification based on a single character, however suggestive it may be, is never reliable. The characters afforded by the pedicellariae are important, but those organs are, like all calcareous formations among echinoderms, liable to great diversity. It is of no special importance in this connection whether the pedicellariae are modified spines or not, the only point being whether, like the spines,

they show great individual variability. The evidence offered by A. Agassiz and Clark (:07) cannot be ignored or denied, and we are therefore forced to conclude that neither spines nor pedicellariae can be depended on to furnish unvarying characters. On the other hand, Duncan errs in placing his reliance almost exclusively on the test and in neglecting the characters afforded by the spines and pedicellariae. The classification used by A. Agassiz and the first one proposed by Döderlein ('87) show a judicious balancing of the various characters, and undoubtedly must serve as the basis for the natural classification we are seeking. Döderlein's latest arrangement of the Cidaridae does not appeal to me as being well-balanced, for many excellent characters afforded by the test and spines are neglected or given little weight, while the interesting diversities of the pedicellariae are permitted to outweigh all else. It seems to me there can be little question, either on *a priori* grounds or as a result of observation, that the characters afforded by the test are the most important in determining relationships among the Cidaridae, and that those of the corona appear to be more reliable than those of the abactinal system and actinostome. The size of the two latter as compared with each other and with the size of the test are useful factors in many cases, but there is considerable individual diversity in these proportions. This is true also of the arrangement of the plates of the abactinal system, the position, form, and size of which nevertheless often furnish characters of very great weight. The primary spines reveal obvious and tempting features, but these must be used with caution, they are generally so variable. Curiously enough, however, in certain cases a character afforded by the primaries is very constant, even though in nearly related species the same character may be very variable. The pedicellariae well repay careful examination and often reveal interesting and constant peculiarities, but, as has already been emphasized, they, like the spines, are subject to great individual diversity. Indeed, it seems to be true that a species which has very variable spines is likely to have equally variable pedicellariae. The secondary, and even the miliary, spines sometimes show characters of real value, although in certain cases they are as variable as the primaries. The calcareous particles in the tube-feet seem to be so uniform in the family but so variable, within these limits, in the individual that they afford no real help in classification.

In the classification set forth in the following pages I have attempted to place the proper value on each of the features of Cidaridean anatomy mentioned above, and I have also taken into account geographical and

bathymetrical distribution. Even the suggestions of size, color, habitat, and habits have not been ignored in the effort to learn the real interrelationships of the species. At the suggestion of Mr. Agassiz, I have included the genera of fossil Cidaridae, as well as the recent forms, in order that the result may be as useful to palaeontologists as to zoölogists, and I have endeavored to give special consideration and due weight to those characters upon which palaeontologists are obliged to rely I am forced to the conclusion, however, that in most cases little value attaches to the presence or absence of crenulation on the tubercles, to the straightness or sinuosity of the ambulacra, or to the amount of confluence of the areolae. While these features are frequently very obvious in fossils, experience with large series of specimens shows that they are very variable in individuals of the same species, and the most striking differences may be due to the age or condition of the specimen. Far be it from me to claim that the genera which I have adopted are all of equal value or that they ought to be adopted as herein defined by all future writers. The genera Phyllacanthus and Stereocidaris are notably unsatisfactory, and it is quite likely that they will be entirely rearranged in the light of further knowledge. Perhaps the same is true of Goniocidaris. But it is hoped that the classification and nomenclature set forth in the following pages may be a real step towards the ideal which we seek.

The Genera.

In attempting to apply the principles outlined above, it will be convenient to begin with those genera which are accepted by A. Agassiz, Döderlein, Mortensen, and Pomel, and virtually by Duncan also. These genera are: —

Cidaris Leske.	Porocidaris Desor.
Goniocidaris L. Agassiz et Desor.	Phyllacanthus Brandt.

Döderlein (:06) has reached the very disturbing conclusion that *papillata* is the type of Cidaris, and that consequently Dorocidaris A. Ag. is a synonym of Cidaris Leske. Acting on this belief, he has introduced Lamarck's name Cidarites for Cidaris as commonly used, and divides it into three subgenera, to one of which he applies the name Dorocidaris A. Ag. In doing this, Döderlein overlooks the very important fact that Leske's *Cidaris papillata* is a composite group which was first broken up by Lamarck. It includes at least three species, — *imperialis*, which Brandt removed to Phyllacanthus; *papillata*, which

A. Agassiz removed to Dorocidaris; and *tribuloides* (or possibly *metularia*; it matters little which), which remains thus as the type of Cidaris. Moreover Brandt, who was the first writer to subdivide Cidaris, distinctly states that *tribuloides* is the type of Cidaris s. str., and as "first reviser" he undoubtedly had the right to select the type. There is therefore no need of upsetting a number of familiar names and causing considerable confusion by insisting on *papillata* as the type of Cidaris. Indeed, if we are to discuss this question, *imperialis* has a better claim than *papillata* to be the type of Cidaris, for it is undoubtedly the first species Leske names, though he has it confused with *papillata* under the varietal name *major*. In resurrecting Lamarck's name Cidarites, which is clearly a substitute for, and synonym of, Cidaris, Döderlein violates the old principle "once a synonym, always a synonym," and certainly if Dorocidaris A. Ag. is a synonym of Cidaris Leske, as Döderlein says, it cannot be used for a subgenus of Cidarites. It is surprising that so good a zoölogist as Döderlein should have committed two such errors. Since Döderlein's Cidarites equals Cidaris Mortensen and his "Cidaris" is equivalent to Dorocidaris A. Ag., the latter can be added to our list of accepted genera, which will also include several genera of recent Cidaridae adopted by Mortensen, Döderlein, and Agassiz and Clark, as follows: —

Dorocidaris A. Agassiz.	Stereocidaris Pomel.
Chondrocidaris A. Agassiz.	Acanthocidaris Mortensen.

We may also add five genera of fossil Cidaridae, accepted by Pomel, Döderlein, and Duncan, regarding which there can be little question: —

Orthocidaris Cotteau.	Polycidaris Quenstedt.
Temnocidaris Cotteau.	Diplocidaris Desor.
Tetracidaris Cotteau.	

The following genera are fully described and figured by A. Agassiz or by A. Agassiz and Clark, and their validity is not likely to be questioned, with the possible exception of Stephanocidaris, which some zoölogists may not wish to separate from Phyllacanthus. So far as the evidence goes, however, it is fully entitled to recognition.

Stephanocidaris A. Agassiz.	Aporocidaris A. Agassiz and Clark.
Centrocidaris A. Agassiz.	Anomocidaris A. Agassiz and Clark.

There still remain no less than 21 genera and several subgenera of Cidaridae which have been proposed and are entitled to consideration.

To these I have given special attention, but the great majority do not seem to me to be based on sufficiently reliable or tangible characters to warrant their recognition. The following list includes them all, with my opinion as to the proper status of each; those which appear to me to be worthy of use are indicated by black-faced type.

Rhabdocidaris Desor: not distinguishable from Phyllacanthus.
Leiocidaris Desor: “ “ “ “
Eocidaris Desor: not distinguishable from Cidaris, or else from Archaeocidaris, according to what species is considered the type. It is true that the first species mentioned by Desor (*keyserlingi*) does not agree with the diagnosis of the genus, but since Döderlein ('87) has definitely selected that species as the genotype, Eocidaris becomes a synonym of Cidaris.
Leptocidaris Quenstedt: very probably not one of the Cidaridae.
Gymnocidaris A. Ag.: not distinguishable from Cidaris.
Prionocidaris A. Ag.: “ “ “ Phyllacanthus.
Schleinitzia Studer: “ “ “ “
Tylocidaris Pomel: apparently a valid genus, though allied to Cidaris.
Typocidaris Pomel: not clearly distinguishable, and too near Cidaris and Dorocidaris.
Pleurocidaris Pomel: not distinguishable from Phyllacanthus.
Plegiocidaris
Paracidaris
Procidaris
Eucidaris
} Pomel: hopelessly indistinguishable.
Anaulocidaris Zittel: not distinguishable from Cidaris.
Discocidaris Döderlein: not “ “ Goniocidaris.
Mikrocidaris
Triadocidaris
Miocidaris
} Döderlein: not distinguishable from each other and too near Cidaris and Dorocidaris.
Phalacrocidaris[1] Lambert: ?
Aulacocidaris[1] Lambert: ?
Tretocidaris Mortensen: see below.
Schizocidaris Mortensen: not worthy of separation from Goniocidaris.
Petalocidaris Mortensen: “ “ “ “ “ “
Histocidaris Mortensen: “ “ “ “ “ Porocidaris.

[1] I have been unable to see the original descriptions or any figures of these two genera, as the papers in which they are published are not to be found in either Cambridge or Boston. But *Aulacocidaris* (Lambert, 1903; Bull. Soc. Hist. Nat. Savoie, (2) VIII, p. 222) is evidently closely related to *Phyllacanthus* and is probably not distinguishable, while *Phalacrocidaris* (Lambert, 1902; Mem. Soc. Geol. France, Pal. IX, fasc. III, Mem. 24, p. 27) is based on Döderlein's living species of *Stereocidaris* from Japan, but includes a number of fossil forms. As *Stereocidaris* is itself only distinguishable with great difficulty, it is very unlikely that *Phalacrocidaris* is tenable.

The genus Dorocidaris is difficult to separate, on the one hand, from Cidaris, and on the other from Stereocidaris, but is particularly close to the latter, and it is almost impossible to draw a sharp line between them. Moreover, it contains a rather heterogeneous lot of species. One of these, *D. micans* Mortensen, seems to be quite unique, and I think it may well be made the type of a new genus for which I would suggest the name **Calocidaris**. The remaining species fall naturally into three groups, distinguished from each other by their abactinal systems, spines, pedicellariae, and distribution. I see no objection to recognizing these groups as genera, and such a course has some obvious advantages. A typical Dorocidaris such as *papillata* has the abactinal system irregularly angular and often indistinctly defined, and the globiferous pedicellariae have a conspicuous end-tooth on each valve. But other species have the abactinal system circular or pentagonal and sharply defined, and some of the globiferous pedicellariae are often more or less like those of Cidaris. To this group *D. bartletti* A. Ag. belongs, and as Mortensen has made that species the type of a new genus, Tretocidaris, that name must attach itself to this section of Dorocidaris, even though few of the species have the remarkable pedicellariae which Mortensen considers the distinguishing character of the genus. Finally, a group of three small species, characterized by their thickened secondaries, globiferous pedicellariae without end-tooth on the valves, sparsely tubercled abactinal system, and antarctic or subantarctic distribution, may be conveniently designated as **Austrocidaris**. The table on the opposite page gives the genera adopted in the present paper, with their authors, the year in which they were proposed, and the type-species of each. The number of recent species in each, which seem to me valid, is also indicated.

The number of fossil specimens to which specific names have been given is in the vicinity of 200; of these, Döderlein lists 135, but there is reason to believe that many of these represent different ages or individual forms of single species, and it is not unfair to assume that the number of extinct species actually known to science does not exceed the number of species now living. The following key will bring out the obvious if not the most important characters by which the 21 genera here recognized may be distinguished. It is hoped that such a key may be of use to palaeontologists as well as to zoölogists. The dimensions are given in millimeters, and the horizontal diameter of the denuded test (abbreviated for convenience to "h. d."), taken at the ambitus, is used as the unit for determining the relative proportions of the various

Genus.	Author.	Year.	Type-species.	Number of Recent Species.
Cidaris . . .	Leske	1778	tribuloides Lamarck	3
Phyllacanthus .	Brandt . . .	1835	imperialis Lamarck	5
Goniocidaris .	L. Agassiz et Desor . . .	1846	geranioides Lamarck	7
Diplocidaris . .	Desor	1854	gigantea Agassiz	0
Porocidaris . .	Desor	1854	veronensis Desor, but of recent species, purpurata Wyv. Thomson	6
Polycidaris . .	Quenstedt . .	1858	multiceps Quenstedt	0
Orthocidaris .	Cotteau . . .	1862	inermis A. Gras	0
Temnocidaris .	Cotteau . . .	1862	magnifica Cotteau	0
Stephanocidaris	A. Agassiz . .	1863	bispinosa Lamarck	3
Chondrocidaris	A. Agassiz . .	1863	gigantea A. Agassiz	1
Dorocidaris . .	A. Agassiz . .	1869	abyssicola A. Agassiz . . .	5
Tetracidaris .	Cotteau . . .	1872	reynesi Cotteau	0
Tylocidaris . .	Pomel . . .	1883	gibberula L. Agassiz et Desor .	0
Stereocidaris .	Pomel . . .	1883	cretosa Mantell, but of recent species, grandis Döderlein .	9
Tretocidaris . .	Mortensen . .	1903	bartletti A. Agassiz	9
Acanthocidaris	Mortensen . .	1903	curvatispinis Bell	3
Centrocidaris .	A. Agassiz . .	1904	doederleini A. Agassiz . . .	1
Anomocidaris .	A. Agassiz and Clark . . .	1907	japonica Döderlein	1
Aporocidaris .	A. Agassiz and Clark . . .	1907	milleri A. Agassiz	3
Calocidaris . .	gen. nov. . .	1907	micans Mortensen	1
Austrocidaris .	gen. nov. . .	1907	canaliculata A. Agassiz . . .	3

21 genera and 60 recent species.

parts. The other abbreviations used are self-explanatory. The "vertical diameter" means the vertical distance from the *margin* of the abactinal system, at the end of an ambulacrum, to the lowest part (usually several millimeters distant from the edge of the actinostome) of the same ambulacrum, measured with a pair of dividers. When the measurement from the *centre* of the abactinal system is normally very different from this, special reference is made to the fact. In all cases maximum measurements are used for comparison; thus, when it is said that the "abactinal system equals .40 h. d.," what is meant is that the *greatest* diameter of the abactinal system (it is not always circular) equals .40 of the greatest diameter of the test. "Primary spines about equal to h. d." means that the *longest* primary is about equal to the greatest diameter of its own test. The relative position of the pores of a pair is indicated as "horizontal" or "oblique," according to whether a line drawn outward from the tubercle on the margin of the median ambulacral area, at right angles to that margin, passes above both pores or

through the outer pore of the pair. Unless otherwise noted, the colors given are those of dried Museum specimens.

In using this, and all other keys given, it should be constantly borne in mind that the younger the individual, the less will it show generic and specific characters; in proportions, number of coronal plates, and of secondary and miliary spines, arrangement of the abactinal system, form of the primary spines, and color, the young are often quite different from the adults. They can only be identified with certainty on comparison with other specimens, old, young, and intermediate, and usually, for very young specimens, it is necessary to know the place and means of collection. On the other hand, unusually large specimens often have the abactinal system and actinostome relatively smaller than in specimens of more moderate size. Variations of five per cent or more, on either side of any mean given, may therefore be expected. The keys are all based on supposedly normal, mature specimens, the age being estimated by the presence and size of the genital openings, the appearance of the primary spines and abactinal system, and to some extent by the size. Although the radial plates of the abactinal system are not connected with any sort of light-detecting or visual organs, they have been so generally called "ocular" (*ocellar* in German and *ocellaires* in French) plates that the name is here retained, as preferable to the alternative term "radial," which Duncan uses, but which is not really quite so distinctive.

Key to the Genera.

Genera marked with an * have no living representatives.

Pores horizontal or nearly so, distant (space between the two of a pair evidently exceeding diameter of a pore); surface of interval flat, or with a groove connecting pores, never elevated. (Individuals in which this feature is obscure are characterized by stout or more or less thorny spines, 1.5–2.5 h. d. [if less than 1.5 h. d., coronal plates very few, 5 or 6], and unsunken and, even actinally, quite distinct areolae.) Recent species exclusively Indo-Pacific.

With pores in 4 more or less regular vertical series in each poriferous zone.

With 4 vertical series of coronal plates in each interradius from actinostome to ambitus . . . . *Tetracidaris*

With only 2 series of coronal plates in each interradius . . . *Diplocidaris*

With pores in only 2 vertical series in each poriferous zone.

Ambulacral and interambulacral plates with more or less numerous, nearly circular pits, irregularly scattered . . . . *Temnocidaris*

Ambulacral and interambulacral plates without such pits.
Abactinal system of numerous thin plates, with very large anal system around which ocular and genital plates form a single narrow ring; genitals, except madrepore, much wider than high, often twice as wide; oculars nearly as high; collar of primaries spotted with white; lowest actinal primaries with very wide collar and a short thick cap of outer layer of spine, flattened, curved, and somewhat serrate at tip, when fully developed . . . *Stephanocidaris*
Abactinal system not as above; collar of primaries not white-spotted; actinal primaries not provided with a distinct cap.
Median interambulacral area less than .30 of interambulacrum *Phyllacanthus*
Median interambulacral area more than .30 of interambulacrum, densely covered with minute tubercles . . . . . . *Chondrocidaris*
Pores nearer together, usually more or less oblique, often separated by an elevation and never yoked together by a groove.
All primary tubercles large, smooth, and imperforate . . . . . **Tylocidaris*
Primary tubercles, at least at ambitus, perforate.
Ambulacra more than half as wide as interambulacra . . . . *Centrocidaris*
Ambulacra not half so wide as interambulacra, usually much less.
Coronal plates with areolae so small their diameter is less than one-quarter horizontal length of plate and only about one-half vertical height . . . . **Orthocidaris*
Coronal plates with areolae which occupy a large proportion of plate.
Ambulacra broad, .35-.45 of interambulacra, with median area correspondingly wide, sometimes sunken and more or less bare; median space of interambulacra, especially along vertical, and inner portion of horizontal sutures, sunken deeper than areolae, especially at angles, and more or less bare; in some species, however, miliary tubercles cover so much of inner half of each coronal plate that parts of vertical suture are concealed and only short, bare, horizontal furrows are visible, and even these may be only faintly indicated. Coronal plates numerous in proportion to h. d., 6–11. Primaries always rough and more or less thorny or prickly, often flaring at tip . . *Goniocidaris*
Ambulacra less than .35 of interambulacra, or, if more than that, primaries not thorny.
Coronal plates numerous and narrow, 9–15, with areolae merging into each other throughout the whole series . . **Polycidaris*
Coronal plates rarely more than 9, areolae at ambitus and abactinally never merged together.
Primary spines long, 2–3 h. d., not at all thorny or prickly, broad and somewhat depressed at base, tapering much but gradually, often slightly curved, and with a conspicuous light-colored or spotted collar, one-fifth or more of the length *Acanthocidaris*
Primary spines very diverse, but never as above.
Only tridentate or, more rarely, bidentate, pedicellariae present, but these abundant and often very large (2–6 mm. high) . . . . *Porocidaris*

Globiferous pedicellariae present, but often only small ones.
Abactinal system very large (.60–.70 h. d.); ambulacral plates few, generally less than 30; poriferous zones not at all sunken; secondary and miliary spines alike, cylindrical and more or less club-shaped; no tridentate pedicellariae present . . . . *Aporocidaris*
Abactinal system less than .60 h. d.; ambulacral plates more than 40 (except, of course, in young individuals).
Abactinal surface conspicuously bare, with no primary spines or well-developed tubercles or areolae much above ambitus; no tridentate pedicellariae present . . . . *Anomocidaris*
Abactinal surface not so conspicuously bare; at least two primary spines well above ambitus in each interradius.
Areolae little or not at all sunken; actinostome generally larger than abactinal system, which is usually .40–.45 h. d.; median ambulacral area with only a single marginal series of tubercles, though there are usually other smaller, scattered tubercles between, and these may form 1–5 vertical series. Primaries .65–1.60 h. d. but commonly about equal to h. d., rather stout, usually blunt; secondaries broad, flat, and truncate . . . . *Cidaris*
Areolae more or less deeply sunken; actinostome usually smaller than abactinal system; median ambulacral area usually with a double marginal series of tubercles, inner much smaller. Primaries 1–3 h. d.; secondaries diverse.
Small (25–40 mm. h. d.); abactinal system with few, generally less than 200, tubercles; secondaries, especially ambulacral, rounded, thickened, and more or less club-shaped; no tridentate pedicellariae; large globiferous pedicellariae with no end-tooth on the valves. Subantarctic, north to about 35° S. . . . . *Austrocidaris*
Larger (30–70 mm); abactinal system with more numerous tubercles; secondaries flat and thin, and usually narrow. Tridentate pedicellariae usually present and large globiferous, often with an end-tooth on the valves. Northern hemisphere, seldom south of the equator.
Abactinal system sharply defined, more or less distinctly circular or pentagonal in outline; ocular plates with outer margin convex or straight, little notched by ambulacra. Some or all of large globiferous pedicellariae, if not like small ones, have curved valves, large terminal opening, and no end-tooth, as in Cidaris . . *Tretocidaris*

Abactinal system not very sharply defined, rather irregular in outline, with re-entering angles, between ocular and genital plates; oculars with more or less concave outer margin or deeply notched by ambulacra. Large globiferous pedicellariae never as in Cidaris.

Abactinal system thick and solid, more or less elevated; genital and ocular plates with more or less convex surfaces, thickly and uniformly covered with tubercles of approximately equal size; ambulacral secondaries usually larger than those on genital, ocular, and uppermost coronal plates and often conspicuously contrasted with them. Coronal plates few, 4–7, rarely 8 or 9; uppermost 1 or 2 or even 3 without primary spines. Primaries never smooth, but provided with longitudinal rows of granules, or with ridges, 1 or more of which may be elevated to form conspicuous, though delicate, buttress-like "wings" along basal half of spine; if these buttress-like "wings" are not present, terminal portion of spine often more or less fluted and flaring. Globiferous pedicellariae, both large and small, commonly lack conspicuous end-tooth . . *Stereocidaris*

Abactinal system flat, usually not uniformly covered with tubercles, some of which are also larger than others; ambulacral secondaries not noticeably contrasted with others abactinally. Coronal plates 6–8, rarely 9, all (except usually uppermost 1, or rarely 2) with primary spines. Primaries sometimes perfectly smooth, never with "wings," and seldom with flaring tip. Globiferous pedicellariae, both large and small, commonly with conspicuous end-tooth.

Median ambulacral area .55 of ambulacrum in width; primaries shining as though polished, white more or less shaded with greenish or pink, or both . . . . . *Calocidaris*

Median ambulacral area less than .50 of ambulacrum; primaries never shining as though polished . . . . *Dorocidaris*

The above key gives little clue to the relationships of the genera with each other, and a natural arrangement must necessarily be largely a matter of speculation. There can be little question that Cidaris is

nearest to the ancestral form and the centre from which the different genera have come. Whether Tylocidaris represents a more primitive type, because of its imperforate tubercles, is an open question. The other genera fall rather naturally into three groups, which correspond to the three "sous-tribus" of Pomel, but the lines between these groups are not clear enough to warrant any recognition of subfamilies. The following table indicates these three groups, and in the succeeding pages the genera will be taken up in the order here given, which indicates roughly their possible relationships.

	Tylocidaris.	
	Cidaris.	
Phyllacanthus.	Goniocidaris.	Dorocidaris.
Chondrocidaris.	Polycidaris.	Tretocidaris.
Diplocidaris.	Orthocidaris.	Calocidaris.
Tetracidaris.		Austrocidaris.
Stephanocidaris.		Centrocidaris.
Temnocidaris.		Aporocidaris.
		Stereocidaris.
		Anomocidaris.
		Acanthocidaris.
		Porocidaris.

Diagnoses of the Genera, and the Recent Species.

In view of the large number of recent Cidaridae described since the publication of A. Agassiz's "Challenger" Echini, a complete revision of the family will not be without value, so, to the extended diagnoses of the genera here accepted, artificial keys to the recent species contained in each are added, with a few remarks concerning each one, and a reference to a good figure when one has been published. Three apparently new species, represented in the Museum of Comparative Zoölogy by several specimens each, are also described and figured. No attempt at a synonymy is made, since the "Revision of the Echini" gives all that is needed in that line for the species long enough known to have been burdened with many names. References to published figures are given for every species which has ever been figured, and photographs are added of all species which have never been figured hitherto, except only *Dorocidaris nuda,* of which no specimen has been available.

TYLOCIDARIS.

Tylocidaris Pomel, 1883, Class. Meth. Gen. Ech., p. 109.

Plate 1054, figs. 1–7, Pal. Franç. Terr. Crét., 7, Cotteau, 1862.

Test small or of moderate size, much as in Dorocidaris; coronal plates 5–8; areolae distinctly sunken, sometimes large, and tending to merge together vertically; primary tubercles large, smooth, and imperforate; median interambulacral and ambulacral areas and poriferous zones as in Cidaris or Dorocidaris; pores large, close together, slightly oblique. Abactinal system of moderate size, about .45–.50 h. d. Actinostome somewhat smaller than abactinal system. Primary spines very stout, club- or acorn-shaped. Secondaries and pedicellariae?

It is difficult to know how much weight can wisely be laid on the absence of perforations in the tubercles, but it is a character never shown in perfect tubercles of living Cidaridae. On the whole, the combination of imperforate tubercles with the curious short, stout spines makes the genus easy to recognize. Döderlein ('87) lists four species, all from the Cretaceous of Europe.

CIDARIS.

Cidaris Leske, 1778. Add. Nat. Disp. Ech., p. 17.

Test moderately high; vertical diameter usually about .60 h. d. (ranges from .50–.75); thick and solid (in *metularia*, thickness of an ambulacral plate at ambitus is about .55 of its horizontal length); coronal plates 6–9 (sometimes 10, very rarely 11); areolae not sunken but tending to merge together actinally; median interambulacral area little or not at all sunken, more or less uniformly tuberculated; sutural lines often not visible at all; ambulacra .20–.35 of interambulacra in width; poriferous zones little sunken; median ambulacral area with a single conspicuous marginal series of tubercles and 1–3 (rarely none, or in large specimens 4 or 5) irregular vertical series of much smaller ones between; sutural lines more or less obscured and not conspicuously sunken; pores oblique, with distance between two of same pair about equal to diameter of a pore and with surface of interval more or less elevated. Abactinal system .30–.50 h. d. Actinostome .40–.55 h. d., usually larger than abactinal system, sometimes half as large again. Primary spines about equal to h. d. (range from .65–1.60 h. d.), stout, cylindrical or terete, usually blunt, slightly rough but not thorny, covered with longitudinal series of granules which are usually low and rounded but may be conspicuous and sharp; actinal primaries not peculiar, little or not at all flattened; ends rounded and generally fluted. Secondary spines flat, truncate, rather broad and not tapering towards tip, which may indeed be widened. Pedicellariae of 3 kinds present as a rule, but tridentate may be wanting, or rarely large globiferous ones fail; latter have curved valves, large terminal opening, and no end-tooth.

This genus is one of the most easily recognized of the family, although some of the individuals with long spines approach quite nearly in appearance to *Tretoci-*

daris affinis. Indeed it is possible that some of the specimens of *C. tribuloides* with long, tapering spines, which have been collected in the West Indies, are really hybrids between that species and *affinis*, but there is no proof that this is the case. There are only 3 valid recent species of Cidaris, and they are quite sharply distinct from each other. The form which Döderlein ('87) described under the name *galapagensis* is not constantly distinct from *thouarsii* and must be referred to that species. All of the living species are littoral forms, and rarely occur at a greater depth than 50 fths., but are found along nearly all tropical and subtropical coasts. Numerous fossil species from Tertiary, Cretaceous, Jurassic, Triassic, and even Permian strata have been named. The following key to the recent species is based on the examination of 845 specimens representing all three.

Key to the Species.

Small, h. d. rarely exceeding 30 mm.; median areas .45–.60 of ambulacral width, usually bare and often sunken; abactinal system .45–.50 h. d.; genital plates always clearly in contact with each other; coronal plates 5 or 6, rarely 7 . . . . *metularia*

Medium to large, h. d. 30–70 mm.; median areas seldom more than .40 of ambulacral width, always provided with miliary tubercles; abactinal system usually less than .45 h. d.; some or all of genital plates separated in mature specimens; coronal plates 7–10, rarely 11.

- Median interambulacral area more than .10 h. d.; abactinal system usually over .40 h. d.; small spines olive, fawn-color, or red-brown, with tips usually darker . . . . *tribuloides*
- Median interambulacral area less than .10 h. d.; abactinal system usually less than .40 h. d.; small spines dark red-brown, purple, or nearly black, with tips not noticeably darker . . . . . . *thouarsii*

Cidaris metularia.

Cidarites metularia Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Cidaris metularia Blainville, 1830, Zoöphytes: Dict. Sci. Nat., **9**, p. 212.

Plate 1g, fig. 1, Rev. Ech., A. Agassiz, 1873.

Although having a far more extensive range than either of the others, this species shows much less diversity in the length and form of the primary spines; they are generally about .80 h. d. and are rarely if ever 1.20 h. d. The stalks of the large globiferous pedicellariae have a well-developed "limb." The colors are generally brighter than in the larger species, and the cross-banding of the primaries is usually very distinct; some Hawaiian specimens are very red, more or less marked with yellowish or reddish white. The geographical range is from Cape of Good Hope, northward on the east coast of Africa into the Red Sea (including Madagascar, Mauritius, Bourbon, and the Seychelles), thence eastward along the

southern coast of Asia with the adjoining islands, through the East Indian archipelego and out into the Pacific, as far as the Solomon, Fiji, and Hawaiian Islands. Curiously enough, *metularia* does not seem to reach either Japan (except the Liukiu Islands) or Australia. The only difference that can be detected between Mauritian and Hawaiian specimens is that, in the latter, the median ambulacral area is somewhat broader and flatter, but the difference is very slight and inconstant.

Cidaris tribuloides.

Cidarites tribuloides Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Cidaris tribuloides Agassiz, 1835, Prodrome, p. 188.

Plate 1d, Plate 2, figs. 1-3, Rev. Ech., A. Agassiz, 1872.

Little need be said further in regard to this well-known species, save that the primary spines are frequently cross-banded, especially in young specimens, and in old specimens are almost always more or less encrusted with colonies of Bryozoa, and similar foreign material. The relative length and thickness of the primaries differ to a remarkable degree in specimens from different localities. The general appearance of specimens from the Cape Verde Islands is thus strikingly different from that of the ordinary West Indian form. On the other hand, many of the specimens dredged in the West Indies, by the "Blake," have the primaries so long and slender that there is a noticeable superficial resemblance to *Tretocidaris affinis*. Connecting forms between the extremes are, however, common. The stalks of the large globiferous pedicellariae have no "limb." The geographical range is confined to the Atlantic Ocean, from the Bermudas and Azores on the north to Brazil, the Cape Verde Islands, and Cape Palmas on the south. In the Museum are several old tests without spines, which are almost certainly this species, labelled "Mer Rouge," but a mistake in labels is always possible, and these have doubtless been mixed at some time with West Indian specimens. There is also a very small (5 mm. h. d.) but perfect specimen from "51° 26′ S. and 68° 5′ W., 57fths.," collected by the "Hassler." If there has been no mistake, this would indicate a remarkable southern range. Small specimens from Ascension Island, Atlantic Ocean, in the collection of the National Museum, like those collected by the "Challenger" at Bahia, and Fernando Noronha, Brazil, have verticillate swellings on the primaries, but are not otherwise peculiar.

Cidaris thouarsii.

Cidaris thouarsii Agassiz and Desor, 1846, Cat. Rais. Ann. Sci. Nat. (3) **6**, p. 326.

Plate 10, Jap. Seeigel, Döderlein, 1887.

This is the well-known substitute for *tribuloides* on the west coast of America. It is easily distinguished from that species by the color and other characters mentioned above. Its range is comparatively limited, however, as it is not known from south of the equator (save in the Galapagos) nor from north of the Gulf of Cali-

fornia. After a careful comparison of numerous excellent specimens from Mexico, Panama, and the Galapagos, it is clear that there is no constant character by which *C. galapagensis* Döderlein ('87) can be distinguished from *thouarsii*. Specimens from the Galapagos usually have the short and very stout spines figured by Döderlein, and apparently do not have tridentate pedicellariae, but some Galapagös specimens have long, slender, tapering spines, while some from the coast of Mexico have spines like those of most Galapagos specimens; and individuals from Panama occasionally lack the tridentate pedicellariae. Döderlein's present opinion (1906) seems to be that *galapagensis* should be regarded as a variety of *thouarsii*.

PHYLLACANTHUS.

Phyllacanthus Brandt, 1835, Prodrome, p. 267.

Test much as in Cidaris but thinner; thickness of an ambulacral plate only .30–.40 of its horizontal length; coronal plates vary greatly in different species, ranging from 5 to 11; areolae not at all sunken and usually quite distinct even near actinostome; median interambulacral area not deeply sunken, though it may be bare and sutural lines distinct; ambulacra .20–.40 of interambulacra in width; poriferous zones little sunken; median ambulacral area generally with a double series of marginal tubercles (inner much smaller than outer) and 1–4 additional, more or less regular, vertical series between; but when ambulacra are very narrow, median area may be as in Cidaris, and when very broad, median area may be bare and without additional tubercles; pores nearly or quite horizontal; distance between two usually much greater than diameter of pore; surface of interval flat or horizontally grooved, so that pores are connected by a furrow. Abactinal system much as in Cidaris. Actinostome varies greatly in different species. Primary spines exceedingly variable, usually 1.5–3 h. d. and quite stout; actinal primaries either as in Cidaris or somewhat flattened, thick and truncated at tip, slightly curved and somewhat serrate. Secondary spines flat, but length and breadth very variable. Large globiferous pedicellariae variable in form and often entirely lacking, but tridentate and small globiferous pedicellariae are generally present.

Large specimens of this genus are easily recognized, but small ones are often puzzling. In very young specimens the pores are arranged much as in Cidaris, and this condition has not wholly disappeared in specimens 20 mm. in diameter; in *thomasii* even the largest specimens do not have the interval between the pores perfectly flat. On the whole the genus is difficult to characterize properly and the recent species are not well defined. But the combination of characters mentioned in the key to genera is unlike that of any other cidaroid, and with proper care a specimen of Phyllacanthus over 30 mm. h. d. should be recognized without great difficulty. No other genus, however, shows so great diversity in the length and form of the spines, and, as might be supposed, the pedicellariae are also very variable. There seem to be only five valid species in this genus, but it must be confessed that the confusion of *baculosa* with *annulifera*, and the latter with *Stephanocidaris bispinosa*, has led to a most unfortunate situation, and there can be no doubt that a careful revision of the genus based upon abundant material from the

Red Sea, Mauritius, the East Indies, and Australia is sadly needed. In the light of such material I believe that additional species will be recognized, and it is quite possible that the genus will need to be divided. For the present, however, I see no better course than to let the genus stand as it is. It seems to be generally agreed that Studer's ('80) *Schleinitzia crenularis* is a Phyllacanthus, probably *annulifera*; while the observations of Döderlein ('87 and : 03) and de Meijere (: 04) show that *Ph. dubia* Brandt ('35) and *parvispina* Woods ('80) are apparently synonyms of *imperialis*. The species designated *australis* by Ramsey ('85) is apparently *baculosa* and *Rhabdocidaris recens* Troschel is clearly *annulifera*. All of the recent species are littoral and are confined to the Indo-Pacific region, but many extinct species have been described from Tertiary, Cretaceous, and Jurassic strata of Europe and America. The following key to the living species is based on the examination of only 118 specimens, but each of the five species is represented by at least four examples.

Key to the Species.

Ambulacra very broad, .40 interambulacra or more; median area broad, sunken and bare; median interambulacral area also sunken and bare; primaries seldom exceed h. d., provided with several whorls of vertical plate-like projections or flat, blunt thorns . . . . *verticillata*

Ambulacra less than .40 interambulacra; median ambulacral and interambulacral areas not conspicuously sunken and bare.

- Collar of primary spines without spots or longitudinal lines of deep red or purple.
  - Coronal plates 5–6 (rarely 7); abactinal system small (.30–.40 h. d.); actinostome large (.50–.55 h. d.) . . . . *imperialis*
  - Coronal plates 6–9 (rarely 10); abactinal system nearly equals or often exceeds actinostome.
    - Primary spines stout 1.5–2.5 h. d., terete, slightly swollen above collar, smooth, or with granules arranged in longitudinal series, becoming ridges near tip; no conspicuous thorns or projections . . . . *thomasii*
    - Primary spines not as above, sometimes flattened at base, usually with conspicuous thorns; collar smooth, reddish or purplish, unspotted . . . . *annulifera*
- Collar of primary spines with noticeable spots of purple or deep red, arranged in longitudinal rows and sometimes merged into lines . . *baculosa*

Phyllacanthus verticillata.

Cidarites verticillata Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Phyllacanthus verticillata A. Agassiz, 1872, Rev. Ech., pt. **2**, p. 151.

Plate 1f, fig. 3, Rev. Ech., A. Agassiz, 1873.

This well-known and unmistakable species reaches a diameter of 35–40 mm. The general coloration is dark brown and green, with the shades lighter in young

individuals. It ranges throughout the East Indian region, north to Anima Oshima in the Liu-kiu Islands and southward along the east coast of Australia; it has been reported from as far west as Mauritius and Zanzibar, and as far east as the Fiji, Samoan, and Hawaiian Islands. Its occurrence in the latter group seems doubtful, as it was not represented in the very extensive collections made by the "Albatross" in 1903. Although ordinarily a littoral form, a specimen from a depth of 547 fths. is reported by de Meijere (:04).

Phyllacanthus imperialis.

Cidarites imperialis Lamarck, 1816, Anim. s. Vert., **3**, p. 54.
Phyllacanthus imperialis Brandt, 1835, Prodrome, p. 268.

Plate 1f, figs. 2, 6, 7, Rev. Ech., A. Agassiz, 1873. Plate 58, figs. 3, 4, Semon's gesam. Ech., Döderlein, 1903.

This is another well-known species, dark brown or purple in color, and of large size (up to 75 mm. h. d). Some or all of the primary spines frequently have two or more narrow rings of light color near the distal end. The geographical range of this species is from the Red Sea and Zanzibar to and throughout the East Indies and along the east coast of Australia. I am in doubt as to whether the varieties recognized by Döderlein are really sufficiently constant to be worthy of names.

Phyllacanthus thomasii.

Phyllacanthus Thomasii A. Agassiz and Clark, 1907, Haw. Pac. Ech.: Cid., p. 15.

Plates 27-30, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This handsome species reaches as large a size as the preceding, and the long, tapering, stout spines give it a very characteristic appearance. In the largest specimens the small spines and test are dark reddish-brown, but in specimens .30–.40 mm. h. d., the ambulacra and their spines are very pale brown, in sharp contrast to the interambulacra and abactinal system. At all ages the primary spines are salmon-colored, thickly spotted with white, and having a brown collar, but in old specimens they are more or less encrusted with foreign material which conceals the true color, and the collar is much wider and darker than in the young. This species is known only from the vicinity of the Hawaiian Islands.

Phyllacanthus annulifera.

Cidarites annulifera Lamarck, 1816, Anim. s. Vert., **3**, p. 57.
Phyllacanthus annulifera A. Agassiz, 1872, Rev. Ech., pt. **1**, p. 150.

Plate 58, figs. 5-11, Semon's gesam. Ech., Döderlein, 1903.

This species has been so persistently confused, on the one hand with the much rarer *Stephanocidaris bispinosa* (q. v.), and on the other with an East Indian variety of the much commoner *Ph. baculosa*, that the limits of its geographical

range are really unknown. There appears to be a variety of *baculosa* common in the East Indies, in which the primaries are cross-banded as in this species, and this form has been confused with *annulifera*. Now if de Loriol ('73) and Mortensen (:03) were correct, it would be clear that Lamarck's *annulifera* is this variety of *baculosa*, and in that case the present species should be called *lütkeni*, as de Loriol clearly figures and describes it under that name. Mortensen says he has examined Lamarck's type and it is *baculosa*, but A. Agassiz examined all of Lamarck's types some forty years ago and satisfied himself that the present species is Lamarck's *annulifera*. In a disagreement such as this it is obvious that the earlier investigation is the one least liable to error, for there had been considerably less time for a chance confusion of labels or specimens. Both de Loriol and Mortensen apparently overlook the fact that A. Agassiz examined Lamarck's types in Paris and that there has never been the slightest reason for supposing that he made any mistake in associating Lamarck's name with this species. Until it can be shown that such a mistake was made, the name it has borne so long should be retained for this species. So far as we now know, it is an Australian and East Indian form, and does not occur in the Red Sea or along the African coast. The Museum of Comparative Zoölogy has two fine specimens from the Gulf of Siam, received from the Copenhagen Museum. They were collected by Mortensen, and labelled by him "Stephanocidaris bispinosa." The species is apparently nearly as variable as *baculosa*, both in coloration and in the form of the primary spines; in some cases the secondaries are green and the primaries cross-banded with purple and green, but in other specimens the secondaries are pale brown and the primaries are dull with less distinct markings. The secondaries usually (perhaps always?) have a median longitudinal stripe, darker than the ground color. The primaries are frequently flattened and widened at the base, tapering to the tip and quite thorny, much as in Stephenocidaris, but they are often nearly cylindrical with few thorns. I am not satisfied that the varieties recognized by Döderlein are sufficiently constant to warrant their recognition by name.

Phyllacanthus baculosa.

Cidarites baculosa Lamarck, 1816, Anim. s. Vert., **3**, p. 55.
Phyllacanthus baculosa A. Agassiz, 1872, Rev. Ech., pt. 1., p. 150.

Plate 1f, figs. 4, 5, Rev. Ech., A. Agassiz, 1873. Plate 59, figs. 1–5, Semon's gesam. Ech., Döderlein, 1903.

Common, variable, and widely distributed as is this much-discussed and perplexing species, its true characters and the limits of their variability are still little understood. It seems useless in the present state of our knowledge to attempt to recognize varieties, and we can only say that with all the diversity of coloration and of primary spines, the deep red or purple spots on the collar of the primaries is an obvious character almost always present. It is true de Loriol ('83) and de Meijere (:04) have described specimens with a narrow unspotted collar, but it is

quite possible that these are not really *baculosa.* It is interesting to note that the purple spots on the collar may merge together, not only longitudinally so as to form parallel vertical lines, but also diagonally, so that the collar appears checkered with light-colored, diamond-shaped spots. These spots are occasionally rounded, and then the color shows some resemblance to that of the primaries of Stephanocidaris. Further evidence of the close relationship existing between that genus and *baculosa* is found in the abactinal system of the latter, where some or all of the ocular plates may be broadly in contact with the anal system. The coronal plates are 8–10 or even 11 in the largest specimens (64 mm. h. d.), and the color is brownish-red or purplish, but is quite variable. The geographical range appears to coincide with that of *imperialis.* A remarkably handsome spine of a Phyllacanthus, quite unlike any of *baculosa* which I have seen, in the Museum collection from "Ile Bourbon," inclines me to Mortensen's (:03) view that the identity of *baculosa* and *pistillaris* is still open to question. If it is not doubtful, this species ought to be called by the latter name, as it has precedence in Lamarck's work. Döderlein (:06), on the strength of Loven's ('87) description and figure, adopts the Linnean specific name *cidaris* for this species, quite overlooking Loven's own statement (p. 146): "Be that as it may, the species name: Cidaris L., left to its fate by the author himself, is to be laid aside as without validity, though of some historical interest." In the collection of the United States National Museum there is a notably fine specimen (No. 14,032) from the Bonin Islands, labelled "*annulifera*"; the secondaries are very long, with a deep brown longitudinal stripe, and the collar of the primaries has some indistinct white spots as well as the characteristic deep purplish-red dots. It is quite possible this is an undescribed species. In the same collection is a large series of specimens from Aden (No. 21,459), which have been labelled by Dr. Mortensen "Cidaris metularia"; the primaries are remarkably short and stout, much as in Cidaris, and as Mortensen did not clean an ambulacrum, it is not strange that he failed to see the very characteristic poriferous zones. But it is hard to understand how he overlooked the conspicuous purple spots on the collar of the primaries.

CHONDROCIDARIS.

Chondrocidaris A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Test much as in Phyllacanthus, but densely covered with minute tubercles bearing miliary spines and small globiferous pedicellariae; median interambulacral area very broad, generally .35–.40 of interambulacrum, nearly flat; ambulacra narrow, only .20–.25 of interambulacra; median ambulacral area covered with about eight vertical series of tubercles, of which the marginal ones are slightly larger; pores horizontal, widely separated, connected by a groove. Abactinal system .35–.40 h. d., with ocular plates entirely excluded from anal system; genitals broadly in contact. Actinostome about equal to abactinal system. Primary spines stout, nearly cylindrical, sometimes slightly tapering, about equal to, or somewhat exceeding h. d., provided with stout, blunt, thorny projections, and often near the tip with longi-

tudinal lamellae. Secondary spines few, flat, and blunt, confined to scrobicular circles and margins of ambulacra; latter very slender. Large globiferous pedicellariae usually wanting; tridentate infrequent, with slender straight valves; small globiferous abundant, on very short stalks, with prominent end-tooth on valves.

This is a monotypic genus, closely related to the preceding but easily distinguished at a glance by the peculiarly bare appearance of both ambulacra and interambulacra.

Chondrocidaris gigantea.

Chondrocidaris gigantea A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Plate 1a, Rev. Ech., A. Agassiz, 1873.

This species is of special interest because of its huge size (up to 95 mm. h. d.), its remarkable primary spines, and its very broad median interambulacral areas densely covered with minute miliaries. The color is brown of some shade, the countless miliaries with a distinctly greenish-yellow cast. It is a curious fact that really young specimens of *gigantea* have not yet been taken, none in the collections of either the National Museum or the Museum of Comparative Zoölogy being less than 75 mm. h. d., and de Loriol's ('**83**) specimen, the smallest yet recorded, was more than half that size. Most of the known specimens are from the Hawaiian Islands, but it is also reported from Lifu, Loyalty Islands (Bell, '**99**), and Mauritius (de Loriol, '**83**). The latter is remarkable for having only 5 coronal plates, while Hawaiian specimens have 8–10. The record of this species from the Lepar Islands, given by Sluiter ('**95**), is said by de Meijere (:**04**) to rest only on spines of "*C.* (*Stephanocidaris*) *bispinosa*."

DIPLOCIDARIS.

Diplocidaris Desor, 1854, Syn. Ech. foss., p. 45.

Plate 1, fig. 5, Syn. Ech. foss., Desor, 1854.

Test much as in Phyllacanthus; coronal plates 7–8; areolae little or not at all sunken, sometimes merging together actinally; median interambulacral area not sunken or bare, but with few, scattered tubercles; ambulacra narrow, less than .25 of interambulacra in width; poriferous zones more or less sunken; median ambulacral area narrow, with usually only a single marginal row of tubercles, the intervening bare space sometimes conspicuous; pores nearly horizontal and widely separated, in vertically very narrow plates, which are so crowded that they have the appearance of having slipped on each other laterally, so that the pores are apparently in 4 vertical series in each zone. Abactinal system small, with large, usually angular, genital and small ocular plates. Actinostome larger than abactinal system. Primary spines very stout, with longitudinal series of low tubercles which tend to merge into ridges near the tip. Secondaries and pedicellariae ?

This genus is very different from any living Cidaridae in the arrangement of the pores, but in all other respects it is strikingly like Phyllacanthus, especially some

specimens of *Ph. imperalis.* The crowding of the pores is very similar to what occurs in Asterias and other starfishes, where the ambulacral plates are so crushed together that a straight, single row of pores is forced into such a zigzag arrangement that it has the appearance of two parallel series. There is no reason to consider the arrangement in Diplocidaris as anything other than a highly specialized condition. It seems strange that it is not found in any living species of Cidaridae. Döderlein (**'87**) lists 5 species of this genus, all from the Jurassic strata of Europe.

TETRACIDARIS.

Tetracidaris Cotteau, 1872, Rev. et Mag. Zoöl. (2), **23**, p. 445.

Plate 29, figs. 7–11, Rev. et Mag. Zoöl. (2), 23, Cotteau, 1872.

Test large, circular at ambitus, somewhat depressed; coronal plates very numerous (16 in each complete vertical series), arranged in 4 series in each interradius from actinostome to above ambitus and thence in a double series to the abactinal system; areolae somewhat sunken; median interambulacral areas narrow and with few miliaries; ambulacra narrow, only about .20 of interambulacra in width; poriferous zones little sunken; median ambulacral area nearly bare, with a marginal series of tubercles and a few scattered miliaries; pores nearly horizontal, widely separated, and crowded into a double series in each zone, much as in Diplocidaris. Abactinal system "large." Actinostome? Primary spines rather slender, nearly cylindrical, somewhat ridged. Secondaries and pedicellariae?

In the arrangement of the pores this species is intermediate between Diplocidaris and Phyllacanthus, but it is not in any sense a connecting link between these genera. It may be regarded as a specialized offshoot of the Diplocidaris branch. Duncan (**'89**) thinks it may be related to Astropyga, and there is some reason for thinking it is not genetically connected with the Cidaridae at all. Only one species is known, *reynesi*, from the European Cretaceous strata.

STEPHANOCIDARIS.

Stephanocidaris A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Test, ambulacra, interambulacra, and relative proportions as in Phyllacanthus, but coronal plates 6–8; abactinal system .40–.45 h. d. and actinostome either larger or smaller; anal system large and made up of numerous plates (in a specimen 42 mm. h. d. there are over 50 anal plates, and in a young specimen 12 mm. h. d. there are 25); all plates of abactinal system relatively thin; genital plates much wider than high, except madrepore, which is much larger than others; ocular plates wide and high, 4-sided, outer side convex, inner usually correspondingly concave; genitals and oculars together form a ring around anal system of

nearly uniform width except where madrepore juts in.[1] Primary spines somewhat flattened near base, conspicuously thorny; collar wide, greenish, reddish or dark with conspicuous white spots; in young specimens these white spots project as granules, but in mature specimens, collar is smooth; actinal primaries slightly curved, with a very wide collar, often more than half their length, and provided with a distinct cap of outer layer of spine; this cap is truncate, thick, and somewhat serrate. Large globiferous pedicellariae are wanting in all available specimens.

Although there can be no doubt of the close relationship between this genus and Phyllacanthus, the discovery of a new species of Stephanocidaris in the Hawaiian Islands, of which numerous specimens are available for study, shows how clearly justified A. Agassiz ('63) was in making *Cidarites bispinosa* Lamarck the type of a separate genus. The characters shown by the primary spines are exhibited in specimens only 12 mm. h. d., and even in these specimens the genital plates are widely separated; it is not, however, until a diameter of over 20 mm. has been reached that the remarkable character of the abactinal system becomes apparent. The three species here recognized are confined to the central and eastern portions of the Indo-Pacific region. The following key is based on the examination of 106 specimens of the first and third species.

[1] It is worth noting that in a young Stephanocidaris 6 mm. in diameter, the ocular plates are all excluded from the periproct, except that of the left posterior ambulacrum, which barely touches an anal plate; in a specimen 7 mm. in diameter, the left posterior ocular is clearly in contact with the anal system and the right posterior ocular barely touches it; in a specimen 12 mm. in diameter, the two posterior, and the left anterior oculars are all clearly in contact with, while the odd anterior ocular barely touches, the periproct; in another specimen of the same size, all the oculars except the right anterior are clearly included; in a specimen 14 mm. in diameter, and in all larger ones, all the oculars are broadly in contact with the anal system. It seems to be true, therefore, of Stephanocidaris that the oculars of the bivium come into contact with the periproct before those of the trivium do and of the latter the right anterior ocular is the last to enter. Examination of a series of young *Cidaris tribuloides* shows that the same course is followed in that species, except that in one specimen the odd anterior ocular was excluded, while the right anterior was no longer so. These facts are strikingly in accord with the condition often found in Tretocidaris and always in Acanthocidaris, where the right anterior ocular is the only one excluded. And I may add that in *Arbacia nigra* and *spatuligera*, in adult specimens of which the posterior oculars, and often the left anterior, are in contact with the anal system, the same course of entrance of the oculars is followed; and while I have found a very few specimens in which the odd anterior ocular is also insert, I have yet to find an Arbacia in which the right anterior ocular is not excluded. The reason for this condition is not clear.

Key to the Species.

Primary spines not red; interambulacral secondaries whitish with a longitudinal green stripe.
- Primaries stout, less than 2 h. d.; ambulacral secondaries dark green; abactinal system larger than actinostome . . . . *bispinosa*
- Primaries slender, 2–3 h. d.; ambulacral secondaries like those of interambulacra; abactinal system smaller than actinostome . . . . . *glandulosa*

Primary spines red (in young, sometimes greenish) with more or less indistinct cross-bands of white; secondary spines reddish or brownish, not longitudinally striped; abactinal system not larger than actinostome . . . . *hawaiiensis*

Stephanocidaris bispinosa.

Cidarites bispinosa Lamarck, 1816, Anim. s. Vert., **3**, p. 57.
Stephanocidaris bispinosa A. Agassiz, 1872, Rev. Ech., pt. 1, p. 160.

Plate 1f, fig, 1, Rev. Ech., A. Agassiz, 1873.

It would be amusing were it not irritating to note how entirely recent writers have ignored Agassiz's (**'73**) description and figure of this beautiful and apparently very rare species. The trouble appears to date from de Loriol's (**'73**) figure, which is certainly not *bispinosa*, but is probably *P. annulifera*, in one of its various color phases; his figure of *lütkeni* is certainly *annulifera*, while his figure of *annulifera* appears to be *baculosa*. Koehler (**'95**) evidently refers to the same form of *baculosa* under the name *annulifera*, while his *Stephanocidaris bispinosa* is probably true *annulifera*. Bedford (**1900**) has apparently identified correctly his specimens of *annulifera*, so far as can be determined from his figures. Döderlein (**:03**) and Mortensen (**:04**) entirely ignore Agassiz's description, or else intimate that the description is inadequate because it fails to apply to their specimens. As a matter of fact, it seems clear that neither of them has seen a specimen of the real *bispinosa*, but since they call the variety of *baculosa* with banded primaries *annulifera*, they are obliged to do something with their specimens of real *annulifera*, and so they suppose them to be *St. bispinosa*, Agassiz's description and figures to the contrary notwithstanding! Their lead is somewhat reluctantly followed by de Meijere (**:04**), who is unwilling to ignore Agassiz's statements; but he, too, records *Ph. annulifera* as *St. bispinosa*. This species reaches a diameter of over 50 mm. Authentic specimens are known only from Australia and Malacca.

Stephanocidaris glandulosa.

Cidaris (*Cidaris*) *glandulosa* de Meijere, 1904, Siboga-Exp. Ech., p. 13.

Plate 1, figs. 5, 6, Siboga-Exp. Ech., de Meijere, 1904.

Among the interesting Echini collected by the "Siboga," in the Dutch East Indies, were 14 small (7–25 mm. h. d.) specimens, taken at depths of 38–51 fths.,

which de Meijere described as *Cidaris glandulosa.* There can be no question of their close relationship to *St. bispinosa*, and it is quite possible, as de Meijere (p. 5) himself suggests, that they are the young of that species. Besides the characters already mentioned in the key, these specimens were remarkable for the number of large globiferous pedicellariae, like those of *P. baculosa*, which they bore.

Stephanocidaris hawaiiensis.

Stephanocidaris hawaiiensis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 18.

Plates 24 and 25, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

A large series of specimens of this handsome species was collected among the Hawaiian Islands by the "Albatross," at depths of 20–320 fths. It is a typical member of the genus, and is not at all likely to be confused with any other species. The largest specimens are 34–42 mm. h. d. and have primaries 90–105 mm. long.

TEMNOCIDARIS.

Temnocidaris Cotteau, 1863, Pal. Franç. Terr. Crét., **7**, p. 355.

Plates 1085–1087 bis, Pal. Franc. Terr. Crét., 7, Cotteau, 1863.

Test large, much like Phyllacanthus; coronal plates 6-8; areolae very distinctly sunken; median interambulacral area broad, well covered with miliary tubercles, with more or less horizontal, narrow grooves and deep, circular pits; ambulacra narrow, .20–.25 of interambulacra; poriferous zones considerably sunken; median ambulacral area with numerous tubercles, often arranged in horizontal series, and with a few deep, circular pits; pores widely separated, more or less nearly horizontal and connected as in Phyllacanthus. Abactinal system apparently larger than actinostome. Primary spines stout, as in Phyllacanthus. Secondaries and pedicellariae?

If Duncan ('89) is correct in his surmise that the pits are of post-mortem origin, Temnocidaris becomes of course a synonym of Phyllacanthus. Until this can be demonstrated, however, the genus is entitled to recognition. The three species which have been named are all from the Cretaceous.

GONIOCIDARIS.

Goniocidaris Agassiz et Desor, 1846. Cat. Rais. Ann. Sci. Nat. (3), **6**, p. 337.

Test moderately high, .50–70 h. d., but not especially thick or solid; coronal plates numerous in proportion to h. d., 6–11; areolae somewhat deeply sunken; median interambulacral areas deeply and distinctly sunken (deeper than areolae, especially at angles), and usually bare along vertical suture, often with short, bare, lateral depressions along inner end of horizontal sutures; in some cases, however, vertical suture nearly concealed and only lateral furrows conspicuous; in still

other cases, even lateral furrows only faintly indicated; ambulacra broad, .35–.45 of interambulacra; poriferous zones more or less sunken; median area much broader than a poriferous zone, usually sunken and often bare along middle; each ambulacral plate bears a single secondary tubercle, a little above inner pore, and in addition 1–8 miliary tubercles, between which more or less space is left bare (amount of bare space varies greatly in different species; in *tubaria*, entire median ambulacral area is sunken and bare save for marginal tubercles, while in *mikado* scarcely any bare spaces are visible; other species clearly connect these two extremes); pores oblique or rarely horizontal; distance between two less than diameter of pore; surface of interval elevated or roughened. Abactinal system variable, ranging from less than .40 to over .50 h. d. Actinostome about equal to abactinal system or smaller. Primary spines very variable, .75–2.00 h. d., always rough, and thorny or prickly; tips of some usually more or less expanded into a large and conspicuous crown, cup, or even plate, which is often only of a little greater diameter than thickest part of spine, but may become as much as .50 h. d.; actinal primaries variable. rough or serrate, usually somewhat flattened; secondaries thick, of moderate length, more or less flattened, rounded at the end. Tridentate pedicellariae wanting, and large, globiferous ones with no end-tooth on the valves.

The typical examples of this genus, such as *tubaria*, are very easily recognized, but it is less easy to place such species as *florigera* and *mikado*. Nevertheless the genus is very generally accepted and seems to be a natural group. Mortensen (:03) has made two new genera (Petalocidaris and Schizocidaris) and a new subgenus (Discocidaris) out of the species here included in Goniocidaris, but none of these rest on anything better than some trifling peculiarity in the large globiferous pedicellariae. Whether we are to find the origin of Goniocidaris in such a form as *Phyllacanthus verticillata* may be open to question, but the median ambulacral and interambulacral areas of that species could easily be transformed into those of *G. tubaria*, while perfectly horizontal pores are found in *G. biserialis*. There can be little question, in any case, that the three southern species are closely related to each other, and the same is true of the Japanese forms, while *florigera* seems to be structurally, as well as geographically, intermediate. The genus is apparently recent and confined to the southern and western Pacific Ocean. The following key is based on the examination of 133 specimens, including all of the species, except *florigera*.

Key to the Species.

Each coronal plate with but few (30–70) secondary and miliary tubercles, median interambulacral area conspicuously bare and often sunken; median ambulacral area commonly without miliary tubercles, except near margin, so that it is often bare and usually much sunken.

Small (20 mm. or less h. d.); coronal plates, 6–8; abactinal system about .50 h. d. and actinostome nearly equal; some primaries taper to a point, while in many specimens, others, abactinal ones, are abruptly and enormously expanded at tip into a plate, diameter of which may be .50 h. d.; primaries usually more or less covered, at least near base, with a coat of woolly, calcareous hairs . . . . *clypeata*

Moderate or large (20–50 mm. h. d.); coronal plates 6–11; abactinal system generally about .40 h. d., and only partially covered with miliary tubercles of various sizes; primaries seldom pointed and with no covering of woolly calcareous hairs.

Abactinal system equal to, or larger than, actinostome; coronal plates with tubercles near vertical suture much smaller than those next to areolae . . . . *tubaria*

Abactinal system smaller than actinostome; coronal plates with tubercles rather large and of nearly uniform size . . . . . *umbraculum*

Each coronal plate with numerous miliary tubercles, so that median interambulacral area is usually covered by them, except on sutures; if bare sunken areas are conspicuous at all, it is only on inner half of horizontal sutures; median ambulacral area with numerous miliary tubercles, tending to cover it, so that it is never wholly sunken and bare.

Large (25–50 mm. h. d.); abactinal system almost uniformly covered with small tubercles; miliary tubercles on ambulacra, in horizontal series with deep furrows between . . . . *geranioides*

Small (15–35 mm. h. d.); abactinal system not uniformly covered with small tubercles; miliary tubercles in median ambulacral area never conspicuous, but often filling up entire space.

Lower edge of ambulacral plates occupied by minute tubercles, leaving distinct bare spaces forming small, rectangular pits, which alternate with each other; primaries white or whitish in contrast with reddish-yellow secondaries . . . . *florigera*

No definite arrangement of tubercles on ambulacra clear, and no distinct bare pits; primaries not "whitish in contrast with" darker secondaries.

Test high, .60–.70 h. d.; abactinal system much less than vertical diameter; primaries more or less covered with calcareous hairs and usually with a conspicuous, flat, horizontal plate just above collar . . . . *mikado*

Test low, .50–.60 h. d.; abactinal system nearly or quite equals vertical diameter; primaries with relatively few, long and stout thorns, but otherwise smooth . . . . *biserialis*

Goniocidaris clypeata.

Goniocidaris clypeata Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 82.

Plate 6, Plate 4, figs. 8–20, Jap. Seeigel, Döderlein, 1887.

This is one of the interesting species discovered by Döderlein in Japan, and will be easily recognized from his excellent figures and description. The prevailing color is whitish, pinkish, or brown of some shade. The material collected by the "Albatross" shows beyond question that the little cidaroid described by Döderlein (**'87**) as *Porocidaris gracilis* is a small example of this species, in which the spines with enormously expanded tips are wanting. The "Siboga" cidaroid called *C. hirsutispinus* by de Meijere (**:04**) is also evidently a young example of this species; the secondaries of *clypeata* are frequently exactly like de Meijere's figure. Except this "Siboga" specimen, *clypeata* is known only from the vicinity of Japan.

Goniocidaris tubaria.

Cidarites tubaria Lamarck, 1816, Anim. s. Vert., **3**, p. 57.
Goniocidaris tubaria Lütken, 1864, Bid. Kund. Ech., p. 137.

Plate 10, fig. 5. Plate 11.

Of this well-known species, nothing further need be said than that it seems to be perfectly distinct from *geranioides*, although the color (light yellowish, red, or deep brownish-red) is the same as that of many specimens of the latter. The geographical range of this species is Tasmania and northward along the east coast of Australia; a specimen labelled "Goniocidaris geranioides? East India" is in the collection of the M. C. Z.

Goniocidaris umbraculum.

Goniocidaris umbraculum Hutton, 1878, Trans. N. Z. Inst., **11**, p. 306.

Plate 10, figs. 3 and 4.

This is the New Zealand representative of the preceding species, and so far as can be determined from the three specimens at hand, is well entitled to specific rank. The bright green color of the test and the larger number of coronal plates (10, as against 8 in *tubaria* of the same size) are good characters in addition to those given in the key.

Goniocidaris geranioides.

Cidarites geranioides Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Goniocidaris geranioides Agassiz et Desor, 1846, Cat. Rais. Ann. Sci. Nat. (3), **6**, p. 337.

Plate 1g, figs. 3, 4, Rev. Ech., A. Agassiz, 1873.

Although this species is quite similar to *tubaria* in general appearance, the differences between them seem very constant; in addition to those mentioned above may be added the frequently darker color (nearly black) and the much less thorny spines of *geranioides*. The geographical range appears to be the same.

Goniocidaris florigera.

Goniocidaris florigera A. Agassiz, 1881, Challenger Echini, p. 46.

Plate 1, figs. 7–20, Challenger Ech., A. Agassiz, 1881.

This "Challenger" species from the East Indies shows the same extraordinary variety in its primary spines which is seen in *clypeata*, and it would be surprising if the pedicellariae were not also variable. As I have no greater confidence in the characters furnished by pedicellariae than I have in those which spines afford, I can find no good reason for recognizing the genera and species based on the "Challenger" material, which Mortensen (: **03**) proposes: — *Discocidaris serrata*, *Schizocidaris assimilis*, and *Petalocidaris florigera*. Certainly if they are to be

accepted, more adequate descriptions are necessary, and the differences between the three species made more tangible. That *C. fimbriata* de Meijere (: **04**) is identical with *florigera* seems to me practically certain.

Goniocidaris mikado.

Discocidaris (*Cidaris*) *mikado* Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 80.
Goniocidaris mikado Döderlein, 1887, Jap. Seeigel, p. 15.

Plate 7, Jap. Seeigel, Döderlein, 1887.

This is another of the Japanese echinoids, which Döderlein's excellent work has given us. Although undoubtedly nearly related to the preceding species and to *clypeata*, it is perfectly distinct and easily recognized. The minute, often nearly spherical, secondary spines are very characteristic. The color is almost cream-white, with a purplish tint abactinally and on the primaries. Specimens have as yet been taken only in the vicinity of Japan.

Goniocidaris biserialis.

Stephanocidaris biserialis Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 79.
Goniocidaris biserialis Döderlein, 1887, Jap. Seeigel, p. 10.

Plate 5, Jap. Seeigel, Döderlein, 1887.

This species is quite unlike the preceding in its general appearance, but resembles it in the obliteration of the bare depressed areas on ambulacra and interambulacra which characterize the typical members of the genus. The color of *biserialis* is quite variable, ranging from dull brownish-yellow, with more or less of a green tint, to yellow, olive-green, or brownish-red. It is known only from the vicinity of Japan.

POLYCIDARIS.

Polycidaris Quenstedt, 1858, Der Jura, p. 644.

Plate 79, fig. 69, Der Jura, Quenstedt, 1858.

Test of moderate size, circular at ambitus, flattened; coronal plates numerous (9–15); areolae somewhat deeply sunken, merging together throughout the entire vertical series, even at ambitus; median interambulacral areas more or less bare and depressed; ambulacra narrow, .15–.22 of interambulacra, straight; poriferous zones little sunken; median ambulacral area with only a single marginal series of small tubercles; pores oblique, near together, separated by a slight elevation. Abactinal system? Actinostome? Spines and pedicellariae?

Döderlein ('**87**) appears to think this genus is near Dorocidaris, but to me it is clear that its relationships are with Goniocidaris. Except for the narrow ambulacra and the merged areolae, *P. nonarius* is strikingly like *G. umbraculum*. Döderlein lists 5 species, all from the Jurassic strata of Europe.

ORTHOCIDARIS.

Orthocidaris Cotteau, 1862, Pal. Franç. Terr. Crét., **7**, p. 364.

Plate 1088, Figs. 1–6, Pal. Franç, Terr. Crét., 7, Cotteau, 1862.

Test of moderate size, circular at ambitus, very little flattened, so that it is subspheroidal; coronal plates numerous (14 or 15); areolae very small, scarcely at all sunken, their diameter less than one-fourth the horizontal diameter of plate at ambitus, and little more than one-half its vertical height; median interambulacral area very broad, covered with miliaries and not sunken; ambulacra narrow, .23 of interambulacra, straight; poriferous zones very narrow, not sunken; median ambulacral area with about 4 vertical series of tubercles; pores oblique, separated by a low elevation. Abactinal system very small, about .25 h. d. Actinostome larger than abactinal system, subpentagonal, about .33 h.d. Spines and pedicellariae?

This is certainly a most un-cidaroid appearing sea-urchin, the straight, narrow ambulacra, the numerous small and nearly uniform miliaries, and the remarkably small areolae and primary tubercles are so unlike the Cidaridae, and yet if the areolae were sufficiently enlarged to merge together vertically, the resemblance to *Polycidaris multiceps* would be quite striking. Only one species has been named, *inermis,* from the Cretaceous of Europe.

TRETOCIDARIS.

Tretocidaris Mortensen, 1903, Ingolf-Exp. Ech., p. 16.

Test moderately high but very variable (.45–.85 h. d.); coronal plates, 4–8; areolae little or moderately sunken, tending to merge together actinally; median interambulacral area more or less depressed, bare or covered with small tubercles, sutural lines usually quite distinct; ambulacra .20–.37 of interambulacra in width; poriferous zones more or less deeply sunken; median ambulacral area with a double series of tubercles along margin, inner much smaller; intervening space may be bare, or more or less covered with scattered tubercles; pores as in Cidaris. Abactinal system .40–.55 h. d., sharply defined, circular, or pentagonal; ocular plates with convex or straight outer margin, little or not at all notched by ambulacra; miliary tubercles covering abactinal system more or less variable in size and somewhat irregularly scattered, leaving bare spaces here and there, especially along margins of genital plates. Actinostome, .37–.50 h. d., generally smaller than abactinal system. Primary spines 1–3 h.d., usually more or less cylindrical or terete, rarely with large and conspicuous thorns, but usually covered with longitudinal series of granules, which may be very low so that spine is nearly smooth or only granular, or may project sharply so that spine is prickly, or may be elevated and merged together so that spine is longitudinally ribbed; actinal primaries equally diverse; secondaries flat and not peculiar. Large globiferous pedicellariae sometimes wanting, sometimes as in Cidaris, sometimes with a very small opening and a powerful end-tooth on valves, and sometimes like small ones, which have a rather large opening and usually an end-tooth.

This genus was established by Mortensen for three recent species (*bartletti, annulata, spinosa*) hitherto placed in Dorocidaris but whose pedicellariae, he

found, were very different from those of *D. papillata.* While the pedicellariae of *bartletti* are much too variable to be used as the basis for a genus, the abactinal system of that species is so noticeably and constantly different from *papillata* that I think the genus Tretocidaris may well be recognized. There are eight other species of Dorocidaris which fall into the same group. It is a much more natural and better differentiated genus than Stereocidaris, which has been quite generally recognized in the last decade. The species of Tretocidaris are widely distributed, occurring in the North Atlantic, the Caribbean and Mediterranean Seas, the Gulf of Panama, northward along the Mexican coast, among the Hawaiian Islands, along the Japanese coast, southward into the East Indies and as far west as Ceylon. I have not attempted to determine whether any extinct species are to be referred to this genus or not. The following key is based on the examination of 938 specimens, representing all of the species recognized except *tiara.*

Key to the Species.

Test very high, .75–.85 h. d.; ambulacra very broad, .33–.37 of interambulacra, with median line bare; primaries with 8 longitudinal ridges (not notched or granular), pale pink at base, olive-green near tip . . *tiara*

Test more flattened, generally less than .70 h.d.; ambulacra generally less than .33 of interambulacra.

Median ambulacral and interambulacral areas bare along vertical sutural line; coronal plates 6–8.

Test moderately flattened or high, .50–.70 h. d.; actinostome moderate, .35–.45 h. d.; median interambulacral area .25 or more of interambulacrum in width, with several series of miliary tubercles on each coronal plate between scrobicular circle and vertical suture; abactinal system fairly well covered with tubercles; primaries 1.25–2.50 h. d.; West Indian.

Abactinal system large, .45–.55 h. d.; areolae at least actinally well-sunken; primaries seldom cross-banded, usually terete, with longitudinal series of numerous minute prickles but never thorny . . . . *affinis*

Abactinal system small, .40–.45 h. d.; areolae very shallow; primaries prettily cross-banded with reddish (or purplish) and yellowish (or greenish), sometimes cylindrical, often terete, frequently flaring at tip, not uncommonly flattened at base, with longitudinal series of rather coarse teeth and often more or less thorny . *bartletti*

Test much flattened, .45–.55 h. d.; actinostome large (.40–.50 h. d.); median interambulacral area .20 of interambulacrum, with only 1 or 2 incomplete series of miliary tubercles on inner end of coronal plates; genital and ocular plates with margins free from miliaries; Eastern Pacific.

Primaries reddish, very slender, 1–1.50 h. d.; thickness of spine about 6 or 7% of length; covered with 14–15 longitudinal series of low, rounded granules; collar and secondaries dark, uniform, brownish-red; no tridentate pedicellariae . . . . *panamensis*

Primaries greenish, often cross-banded with darker, stout, about equal h. d.; thickness 8-12 % of length; covered with 12–13 longitudinal series of coarse, sometimes sharp granules; collar light reddish or whitish; secondaries greenish, with a broad longitudinal stripe of brownish- or purplish-red at tip; tridentate pedicellariae common . . . . *dubia*

Median ambulacral and interambulacral areas not at all bare.

Coronal plates 4 or 5, rarely 6 even in large specimens; primaries slightly swollen near base, terete, almost smooth; large globiferous pedicellariae wanting . . . . *calacantha*

Coronal plates 6–8, rarely 5 even in small specimens; primaries not as above.

Areolae very small, those on largest coronal plate only .60–.65 of length of plate; abactinal system .40 h. d. and actinostome .35 h. d. . . . . *perplexa*

Areolae moderate or large, those on largest coronal plate .70–.75 of length of plate; abactinal system about .50 h. d. and actinostome about .45 h.d.

Primary spines somewhat flattened, at least near base, with about 10 longitudinal series of coarse, sharp granules which usually become fused near tip into ridges; in old specimens these ridges may occupy entire length of spine, no separate granules being visible, while in other cases granules may be conspicuous as sharp prickles almost entire length of spine; primaries white or whitish, spotted or banded with brownish-red or purple; collar very narrow . . . . *bracteata*

Primary spines terete, with 12–15 longitudinal series of fine, sharp granules which do not lose their individuality entirely, even near tip of old spines; unicolor, white or pale yellowish; collar of moderate width . . . . *reini*

Tretocidaris tiara.

Dorocidaris tiara Anderson, 1894, Journ. Asiat. Soc. Bengal, **63**, p. 188.

Plate 5, figs. 2, 2a, Ill. Investigator Zoöl. Ech., Alcock and Anderson, 1895.

This is one of the species collected by the "Investigator," the real position of which is somewhat doubtful, although the figures given in "Illustrations . . . Zoölogy . . . Investigator" (1895, pt. 2, plate 5, figs. 2 and 2a) indicate its position in Tretocidaris. The test is extraordinarily high, even though the measurements given by Anderson represent some other method of estimating the height of the test than that which is here used. There are several reasons why *tiara* is not synonymous with *St. indica* Döderlein, as has been suggested, but it is still more incredible that it should be *T. bracteata*, as Mortensen (: **03**, p. 173) asserts, unless Anderson's description and figures are to be entirely ignored. Either Mortensen has not seen a specimen of *bracteata*, or else his supposed specimen of *tiara* is not *tiara* at all. Anderson's figures and description are remarkably clear and complete, and unusually satisfactory, although he

fails to mention the pedicellariae. The test of *tiara* is chestnut-brown, green abactinally, especially towards the anus; the secondaries are olive-green with a darker longitudinal band. The largest specimen was 42 mm. h. d. The only recorded locality for *tiara* is off Colombo, Ceylon, in 142–400 fths.

Tretocidaris affinis.

Cidaris affinis Philippi, 1845, Arch. Naturg., **11** Jhrg., 1, p. 351.

Plate 1, fig. 5, Rev. Ech., A. Agassiz, 1872. Plate 1, fig. 1, Ingolf-Exp. Ech., Mortensen, 1903.

This well-known species has been confused with *Dorocidaris papillata* so long that it may be hard to believe it is really quite different. We are indebted to Mortensen (:**03**) for showing its right to specific rank (although he makes no reference to the abactinal system !), but we cannot follow him in placing it in the genus Cidaris. Mediterranean and West Indian specimens appear to be alike in all particulars ; Mortensen says the tridentate pedicellariae were wanting in his Mediterranean specimens, but those in the collection of the M. C. Z. from Cape Sagras and from the Mediterranean have them normally developed. Mortensen says the spines are 1–1.5 h. d., but our large series of specimens show a much greater range, 1.25–2.40 h. d. The largest specimen is 38 mm. h. d. The color is variable, but the small spines of the test are more or less greenish, tipped with dark red, while the entire abactinal system (or at least the sutural lines) and the bare areas on ambulacra and interambulacra are dark red ; the primaries are dull grayish, more or less pink or white near base, and with a greenish or brownish collar. In West Indian specimens the color is often very light, the secondaries and test being nearly cream-color with the former tipped with reddish. In other West Indian specimens the color is sometimes nearly slate-color, with little trace of reddish. This species ranges throughout the North Atlantic eastward into the Mediterranean, and southwestward to Barbados and the Gulf of Mexico, down to a depth of 500 fths.

Tretocidaris bartletti.

Dorocidaris Bartletti A. Agassiz, 1880, Bull. M. C. Z., **8**, 2, p. 69.
Tretocidaris bartletti Mortensen, 1903, Ingolf-Exp. Ech., p. 16.

Plates 8 and 9. Also Plate 2, figs. 16–27, Blake Ech., A. Agassiz, 1883.

In his original description Agassiz called attention to the resemblance between the primary spines of this species and of Stephanocidaris. Young specimens of *bartletti*, for this reason, show quite a striking resemblance to young specimens of that genus, but a careful examination shows important differences in the primaries as well as in the test. In spite of the very great diversity exhibited in both its spines and its pedicellariae, there can be no question as to the real relationship of this species. Mortensen (:**03**) names two closely allied, supposedly new species, which he found in the British Museum ; one, *annulata*, I am unable to distinguish

from *bartletti*, for no characters are given which do not occur in some specimens of that species; the other, *spinosa*, may prove to be a valid species, but its affinities cannot be determined from the published description. The largest specimen of *bartletti* in the collection of the Museum of Comparative Zoölogy is 49 mm. h. d.; another (Plates 8 and 9), not quite so large (47 mm. h. d.), has the longest spines 93 mm., nearly all cylindrical and not at all thorny. The test of these specimens is brown, varying from fawn-color to deep red-brown, or even deep red on the abactinal system. In the National Museum there is a magnificent specimen of *bartletti* 68 mm. in diameter. This species is known only from the West Indies in 88–397 fths.

Tretocidaris panamensis.

Dorocidaris panamensis A. Agassiz, 1898, Bull. M. C. Z., **33**, p. 73.

Plates 1, 2, Pan. Deep Sea Ech., A. Agassiz, 1904.

This handsome species is the Pacific representative of *T. affinis*, but is quite obviously distinct. The tridentate pedicellariae are wanting in all of the thirteen specimens examined, of which the largest is 35 mm. h. d. The geographical range of *panamensis* seems to be limited to the west coast of Central America and around Cocos Island, in 66–112 fthms.

Tretocidaris dubia, sp. nov.

Plate 6, figs. 3 and 4.

Test somewhat flattened; vertical diameter about .52 h. d.; coronal plates 6; areolae distinct and not very deeply sunken; median interambulacral area not sunken, very sparsely covered with tubercles, only 6 or 7 on each coronal plate in addition to the scrobicular circle; ambulacra wide, nearly .40 of interambulacra; poriferous zones broad and little sunken; median ambulacral area with a double series of rather large tubercles on each margin, with space between perfectly bare; pores slightly oblique, rather large. Abactinal system .45–.50 h. d., nearly circular, and clearly defined, elevated at centre, very sparsely covered with small secondary spines; genital plates rather large, higher than wide, with pores near outer edge; ocular plates more or less triangular, one (right anterior) or more excluded from anal system, which is about one-half of abactinal system and has an outer series of 7–10 rather large plates and 9–12 smaller ones at centre; all plates of abactinal system carry a few rather coarse tubercles of nearly uniform size; each genital plate has 14–20 ± such tubercles and each ocular, 8–12 ±. Actinostome slightly smaller than abactinal system, not at all sunken, closely covered with stout plates, 3 or 4 in each interambulacrum and about 8 or 9 pairs in each ambulacrum. Primary spines short, about equal to h. d., nearly cylindrical, seldom tapering, but often truncate or slightly flaring at tip, covered with 12–13 low, longitudinal series of coarse, sometimes sharp granules; actinal primaries much as in Cidaris and usually longitudinally ridged at tip; secondaries long and narrow, flat and slightly widened at tip. Pedicellariae not peculiar; large and small globiferous, as in *panamensis*; tridentate much as in *affinis*. General color of test decidedly greenish, especially abactinally, but anal system reddish-brown; miliary and secondary

spines whitish, longitudinally striated with deep reddish-purple; on secondaries, striations merge to form a broad stripe at tip of spine; primary spines dull grayish, sometimes indistinctly cross-banded with brown; collar flesh-color or whitish. Largest specimen 25 mm. h. d.; vertical diameter, 13 mm.; abactinal system, 12 mm.; actinostome, 11 mm.; longest primary, 25 mm., a trifle more than 2 mm. thick at base.

That this species is closely related to *panamensis* seems clear, but that it is quite distinct is certainly indicated by the available material. None of the specimens of either are in any way intermediate. Both species were taken by the "Albatross" at Station 3378, in 112 fathoms off Galera Point, Cape San Francisco, Ecuador, but only *panamensis* was found near Cocos Island, and only *dubia* at Station 3397, in 85 fathoms off Galera Point. Possibly *dubia* is a more southern species; at any rate, it is known only from the coast of Ecuador.

Tretocidaris calacantha.

Dorocidaris calacantha A. Agassiz and Clark, 1907, Haw Pac. Ech. Cid., p. 11.

Plates 13, 14, 34, 35, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This very distinct species reaches a size of 43 mm. h. d., with spines 81 mm. long. It is very pale brown with a greenish cast, especially on the abactinal system; the secondaries each have a broad green stripe; the primaries are very faintly banded with brown and at the base are finely spotted with white. This is one of the species found by the "Albatross" at the Hawaiian Islands, where it is not rare in 127–198 fths.

Tretocidaris perplexa, sp. nov.

Plate 6, figs 1 and 2; and Plate 7, figs. 1–4.

Test somewhat flattened; vertical diameter, about .55 h. d.; coronal plates 7 or 8; areolae small, only .60–.65 of horizontal length of plate, distinct and not very deeply sunken; median interambulacral area very fully covered with tubercles, smallest next to vertical suture, which is quite distinct; ambulacra about one-third of interambulacra in width; poriferous zones, broad and little sunken; median ambulacral area with a double series of tubercles on each margin, inner much smaller, and between these, 3–6 irregular series of small tubercles which sometimes, but not always, conceal vertical suture; pores nearly horizontal, large, their horizontal diameter much exceeding vertical. Abactinal system about .40 h. d., nearly circular and clearly defined, flat and quite thickly covered with small secondary spines; genital plates rather large, nearly square or somewhat pentagonal, with pores near outer edge; ocular plates more or less triangular, with apex truncated, when in contact with anal system, either wholly excluded, or some, or all except right anterior one, in contact with a large anal plate; anal system about one-half of abactinal, with an external series of 10–12 large plates and 12–15 smaller ones at centre; except along margins all plates of abactinal system covered with rather coarse tubercles of nearly uniform size; each genital plate has 50–80 ± such tubercles and each ocular 20–35 ±. Actinostome small, only about .35 h. d., not at all

sunken, closely covered with stout plates, 4 in each interambulacrum and about 10 pairs in each ambulacrum. Primary spines short, about equal to h. d., nearly cylindrical, seldom tapering, but often flattened and widened at tip, covered with 14–24 longitudinal series of coarse, sharp granules; actinal primaries much as in Cidaris and nearly smooth; secondaries, long and narrow, but rather thick and often with a deep longitud.nal furrow on outer surface at tip, which is thus crescent-shaped in cross-section. Pedicellariae not peculiar; no large globiferous ones were found, but small globiferous and tridentate, like those of *dubia*, are frequent. General color of test decidedly greenish, especially abactinally; miliary spines greenish; secondary spines greenish with a broad longitudinal stripe of deep reddish-purple; primary spines dull grayish with a bright olive-green base and collar. Largest specimen, 50 mm. h. d.; vertical diameter, 27 mm.; abactinal system, 20 mm.; actinostome, 18 mm.; longest spine, 40 mm., 3 mm. thick at base, 5 mm. wide at tip.

In some ways this species is much like *dubia*, but aside from the differences in the tuberculation of the test, the small areolae, abactinal system and actinostome, and the short primaries with olive-green collar and conspicuously flattened tips, are very characteristic of *perplexa*. The resemblance between the two species in the color of the secondary spines is quite noticeable. Two of the five known specimens of this species were collected by the "Albatross" in the Gulf of California on a bottom of coarse sand, in 36–39 fathoms. The other three are said to have been picked up on the shore of Clarion Island, the westernmost of the Revilla Gigedo Islands.

Tretocidaris bracteata.

Dorocidaris bracteata A. Agassiz, 1879, Proc. Amer. Acad., **14**, p. 197.

Plate 10, figs. 1 and 2.

This is apparently the East Indian representative of *bartletti*, though it is a smaller species and obviously quite different. Mortensen (: **03**), on the supposed characters of the large globiferous pedicellariae, places *bracteata* in Stephanocidaris, but as we have already seen, he probably did not have a specimen of that genus for comparison. Moreover, the pedicellaria which he figures as a "large globiferous" of *bracteata* is exactly like the *small*, globiferous pedicellariae of this species, while the large globiferous pedicellariae of this species are actually like those of Cidaris. However, these large ones are very infrequent and may be wanting, while the small ones are often very large, and it is apparently one of these latter that Mortensen has figured as the characteristic pedicellaria of Stephanocidaris! It seems to me that this serves as an illustration of the danger of relying on the pedicellariae. This species is relatively small, the largest specimen being only 29 mm. h. d. The secondaries are pale purple or rose, with or without yellowish tips, or flesh-colored with a longitudinal rosy stripe; in old specimens those of the ambulacra may be darker than those of the interambulacra, and thus noticeably contrasted with them, and the abactinal system is dark brownish-red; the primaries always show more or less clearly the dark markings, which are usually pur-

plish, but may be reddish or greenish. Originally discovered by the "Challenger" near Amboina, this species has since been taken only by the "Albatross" in Sagami Bay, Japan. Its bathymetric range is 15–114 fms.

Tretocidaris reini.

Cidaris (*Dorocidaris*) *reini* Döderlein, 1887, Jap. Seeigel, p. 7.

Plate 4, figs. 1–7, Jap. Seeigel, Döderlein, 1887. Plate 1, figs. 2, 3, Siboga-Exp. Ech., de Meijere, 1904.

Although this species is closely related to the preceding, the material at hand supports Döderlein's opinion that his Japanese specimens were a new species; curiously enough, however, he makes no reference whatever to *bracteata!* The primary spines of the two species are quite distinct, as already shown; the ocular plates of *reini* are narrower and higher than in *bracteata* and more broadly in contact with the anal system, and the difference in color is very marked; when *reini* is not uniformly yellowish with dull white spines, the uppermost coronal plates, the interambulacral miliary spines, the genital plates and the anal system are deep reddish, while the ocular plates and ambulacra with all their spines are pale yellowish in marked contrast, just the opposite of the coloration in *bracteata;* the primaries of *reini* are apparently not banded or spotted in adults, but if de Meijere's identification of his small East Indian specimens is correct, the young must be very much like those of *bracteata*. In size and in the pedicellariae, the two species agree well; the largest *reini* reported is 34 mm. h. d. Excepting the four young Cidaroids taken by the "Siboga" near the Kei Islands and Timor which de Meijere refers to this species, but which might just as naturally be called *bracteata*, *reini* has not been taken yet anywhere but in Sagami Bay and Kagoshima Gulf, Japan, in 83–158 fths.

DOROCIDARIS.

Dorocidaris A. Agassiz, 1869, Bull. M. C. Z., **1**, p. 254.

Test much as in Tretocidaris, but ranging up to only .70–.75 h. d. Abactinal system very different, its outline not often sharply defined and rather irregular, with re-entering angles between genital and ocular plates; latter more or less pentagonal and deeply notched by ambulacra. Primary spines cylindrical, at least near base, or terete, sometimes smooth, but usually with longitudinal series of granules, or ridges, never "winged" however, and generally not flaring at tip. Globiferous pedicellariae, both large and small, with a conspicuous end-tooth on the valves; tridentate pedicellariae usually present.

Although this genus is quite easily distinguished from the preceding, the line of division between it and Stereocidaris is exceedingly hard to draw, and it is an open question whether there is sufficient ground for keeping them separate. As small genera are more convenient and wieldy, however, we may retain the division recognizing that the line is a very arbitrary one. As here used, Dorocidaris includes five species, which are found only in the Atlantic Ocean and almost entirely

north of the equator. Numerous fossil Cidaridae from Tertiary, Cretaceous, Jurassic, and possibly even Triassic strata are to be referred to either this genus or the preceding. The following key is based on the examination of 536 specimens, representing all of the living species, except *nuda*.

Key to the Species.

Primary spines more or less white and smooth, rarely conspicuously granular, prickly, or ridged, and neither flaring nor conspicuously flattened at tip; median ambulacral area less than .50 of ambulacrum and almost wholly covered with small tubercles . . . . *abyssicola*

Primary spines more or less prickly, granular, or ridged.

Each coronal plate with only a few tubercles on inner half (generally less than 25, not counting scrobicular circle); sutural line of ambulacra usually distinctly visible; each ambulacral plate with 1 or 2, seldom 3, tubercles; primaries more or less cylindrical, often flaring at tip, and never conspicuously flattened there; median interambulacral area less than .25 of interambulacrum in width; sutural line usually quite distinctly sunken and bare.

Whole abactinal surface well covered with light-colored secondary and miliary spines . . . . *papillata*

Whole abactinal surface appearing noticeably bare from small number of secondary and miliary spines present; test light-colored, but all spines reddish-brown or purple . . . . *nuda*

Each coronal plate with numerous (more than 30) tubercles on inner half; sutural line of ambulacra often not visible, each plate with 2–5 tubercles.

Median interambulacral area less than .25 of interambulacrum; sutural line quite distinct; abactinal system with numerous tubercles (genital plate with 110 ±; ocular with 30 ±); primaries often flattened near tip, sometimes greatly expanded into broad flat fans . . . . *blakei*

Median interambulacral area often more than .25 of interambulacrum; sutural line well concealed by tubercles; abactinal system with rather few, large tubercles (genital plate with 55 ±; ocular with 20 ±); primaries terete, covered with sharp granules and never either conspicuously flattened or flaring at tip . . . . *rugosa*

Dorocidaris abyssicola.

Dorocidaris abyssicola A. Agassiz, 1869, Bull. M. C. Z., **1**, p. 253.

Plate 1, figs. 1–4, Rev. Ech., A. Agassiz, 1872.

This species seems to be quite distinct from *papillata*, and while it is occasionally much like *blakei* or *rugosa* in certain features of the test, the primaries commonly distinguish it from either of them at a glance. In addition to the characters given in the key may be mentioned the following: the abactinal system is very large (.48–.55 h. d.), while the actinostome is relatively quite small (.35–.45 h. d. but only .70–.80 of the abactinal system); the test is usually under

.60 h. d. in vertical diameter, and it, as well as the secondaries, is pale brown or yellowish; the abactinal system is sometimes quite red; the uppermost coronal plates do not carry primaries, and even the second ones may lack a well-developed spine; the primaries are usually about 1.25 h. d. and never exceed 2 h. d. The diameter of the test is usually about 25 or 30 mm. but is sometimes 35 or 40, and the largest specimen is 68 mm. h. d. This species ranges from St. Lucia northward to the coast of South Carolina and the region south of Martha's Vineyard at depths of 100–200 fths.

Dorocidaris papillata.

Cidaris papillata Leske, 1778, Add. Nat. Dis. Ech. Klein, p. 61 (*partim*).
Dorocidaris vapillata A. Agassiz, 1869, Bull. M. C. Z., **1**, p. 254.

late 1b, Rev. Ech., A. Agassiz, 1872.

Nothing more need be said of this well-known species than that it does not seem to occur in the western part of the Atlantic, but is apparently confined to the northern and eastern parts of that ocean and to the Mediterranean Sea. The bathymetric range is from a few fathoms down to about one thousand. Mortensen's (:**03**, p. 170) assurance that the "Challenger" specimen from St. Paul's Rock is really *papillata* is important in this connection, but I think it possible that the individual may prove to be *rugosa!* In size *papillata* reaches a diameter of 58 mm., while in color it is quite variable, ranging from grayish-white to reddish-yellow, becoming brick-red on the abactinal system, with dull grayish or yellowish primaries.

Dorocidaris nuda.

Dorocidaris nuda Mortensen, 1903, Ingolf-Exp. Ech., p. 171.

This species is apparently distinct from all the other members of the genus, but its real relationships can only be determined when it is more fully described. Possibly it is not so closely allied to *papillata* as I have assumed. The size is not mentioned, but the test is white and the spines purple or reddish-brown. It has been taken only in the Gulf of Guinea and near the Cape Verde Islands, in 53–250 fths.

Dorocidaris blakei.

Dorocidaris Blakei A. Agassiz, 1878, Bull. M. C. Z., **5**, p. 185.

Plate 4, Bull. M. C. Z., 5, 9, A. Agassiz, 1878. Plate 1, Blake Ech., A. Agassiz, 1883.

This is one of the most interesting discoveries of the "Blake," and specimens with fully developed primaries are indeed unique. The color is grayish with more or less of a yellow-brown tinge to the test. The largest specimen is 37 mm. h. d. with spines 76 mm. long. Specimens in which there are none of the conspicuously flattened primaries are easily recognized by the large abactinal system,

.45–.55 h. d., almost uniformly covered with small tubercles; the narrow poriferous zones, about .20 of ambulacra, and the numerous small tubercles on the interambulacra. This species ranges from Havana to Barbados in 197–450 fths.

Dorocidaris rugosa, sp. nov.

Plates 4 and 5. Plate 7, figs. 5–8.

Test rather high, vertical diameter about .60 h. d.; coronal plates 7; areolae deeply sunken and distinct; median interambulacral area very fully covered with tubercles, smallest next to vertical suture, which is quite distinct; ambulacra less than one-third of interambulacra in width; poriferous zones narrow and deeply sunken; median ambulacral area with a double series of marginal tubercles, inner much smaller, and between these some small scattered tubercles tend to conceal vertical suture; pores oblique, small. Abactinal system about .45–50 h. d., irregular in outline, stout and heavy somewhat as in Stereocidaris, covered with rather coarse tubercles; genital plates somewhat pentagonal, with lateral margins concave, and pores not far from centre; ocular plates more or less pentagonal, usually wholly excluded from anal system, but posterior ones sometimes in contact with anal plates, more or less notched on outer edge by ambulacra; anal system not quite one-half of abactinal, with an external series of 10–12 large plates and 12–15 smaller ones at centre; except along margins all plates of abactinal system covered with rather coarse tubercles of nearly uniform size; each genital plate has 50–60 ± such tubercles and each ocular plate 20–30 ±. Actinostome small, about .40 h. d., not at all sunken, closely covered with stout plates, 5 in each interambulacrum and about 10–12 pairs in each ambulacrum. Primary spines long, 2–2.5 h. d., terete, usually swollen just above collar, and thence tapering to tip, covered with 12–16 longitudinal series of conspicuous sharp granules; actinal primaries slightly flattened, a little curved and somewhat serrate; secondaries not peculiar, of moderate length and width, flat, blunt, or truncate at tip. Pedicellariae as in *papillata*. General color of test yellowish or brownish, more or less rose-red or brick-red, abactinally; secondaries and miliaries same as test; primaries whitish or grayish, abactinal ones sometimes bright rose; neck smooth, polished, white, brownish, or pink; collar narrow, pale brownish or rarely lighter than neck. Largest specimen in the Museum of Comparative Zoölogy, 40 mm. h. d.; vertical diameter, 24 mm.; abactinal system, 20 mm.; actinostome, 17 mm.; longest primary, 80 mm., 5 mm. thick near base, somewhat more than 1 mm. thick at tip. In the National Museum is a fine specimen 60 mm. h. d.

This species is clearly the representative of *papillata* in the western Atlantic, but may be readily distinguished from that species by the broader and more completely covered median interambulacral area, the much more fully tubercled median ambulacral area, the more uniformly tubercled abactinal system, and the terete and very prickly primary spines. The distribution of *rugosa* is only imperfectly known; the specimens I have examined are from stations between 32° N. lat. (off Savannah, Ga.) and Barbados and St. Vincent, in 164–337 fathoms. There are 8 specimens in the collection of the U. S. National Museum, several of which have been labelled by Mortensen. One (No. 21,444) is labelled "Stereocidaris ingolfiana," which is a very natural mistake, as small

specimens of the two species are very difficult to distinguish. The others are labelled "Dorocidaris papillata," which is what one would naturally call them, if *rugosa* is not to be recognized as valid.

CALOCIDARIS, gen. nov. (Greek, καλός, beautiful, + *cidaris*).

Test large and rather high; coronal plates 7 or 8; areolae distinct and considerably sunken, the most actinal tending to merge together vertically; median interambulacral area not at all sunken, covered with numerous miliaries and with more or less horizontal grooves or narrow furrows, such as occur in Temnocidaris; ambulacra about .25 of interambulacra in width; poriferous zones scarcely at all sunken; median ambulacral area very wide, about .55 of ambulacrum, with very few tubercles aside from the customary double marginal series; pores oblique, large and close together. Abactinal system not quite .50 h. d., of very irregular outline; ocular plates deeply notched by ambulacra. Actinostome very small, only about .65 of abactinal system. Primary spines 3 h. d., cylindrical, white, smooth, and polished like porcelain, more or less tinged with pink and green; actinal primaries flat and longitudinally fluted, but not notched or serrate. Secondaries flat and tapering, many bluntly pointed. Pedicellariae as in Dorocidaris.

Although in many respects like Dorocidaris, the very broad and nearly bare median ambulacral areas, the remarkable color, and especially the smooth, polished primaries, mark this genus at a glance. The largest primaries are all broken in the specimen in the Musum of Comparative Zoölogy, so that their length is not shown in the figure given. But a specimen in the U. S. National Museum, which is the most beautiful echinoid I have ever seen, is nearly perfect. The primaries are 160 mm. long, rather more than 3 times the diameter of the test, and scarcely taper at all, but are cylindrical throughout their entire length. The genus is monotypic and very few specimens are known. The above description is based on a specimen 61 mm. h. d., from near Barbados, but two other specimens in the U. S. National Museum have been examined.

Calocidaris micans.

Dorocidaris micans Mortensen, 1903, Ingolf-Exp. Ech., p. 23.

Plate 3.

This is easily the handsomest, as well as one of the largest, of the West Indian cidaroids. It reaches a diameter of more than 60 mm. The test is white, and the secondaries nearly so, but the abactinal system and adjoining coronal plates are pale green; the primaries when dry are shining white, with a pink base and occasional faint, irregular marks of the same color; they look as though artificially polished. In alcoholic specimens the spines have a greenish shade and the pink is deeper. The only known specimens of this beautiful species were taken by the "Albatross" off the northwestern coast of Cuba in 205 fths., and by the "Blake" off Barbados in 125 fths.

AUSTROCIDARIS, gen. nov. (Latin *auster*, the south wind, + *cidaris*).

Test flattened, .50–.60 h. d., but otherwise much as in Dorocidaris; abactinal system much more sparsely covered with miliaries; secondaries more or less nearly cylindrical and thickened at tip; primaries generally short, often less than h. d., and usually smooth (in individuals where primaries are long and rough, secondaries are nearly flat, so that resemblance to Dorocidaris is marked). Tridentate pedicellariae wanting and globiferous pedicellariae with no end-tooth on valves; eggs and young carried by female (*mortenseni?*).

Were it not for their geographical isolation it would hardly be worth while to attempt the separation of these three small species from Dorocidaris, but as they have the above given peculiarities in common and are probably more nearly related to each other than to any other forms, it is convenient to keep them apart. They are confined to the southern parts of the Atlantic and Indian oceans, their known range extending from 75° W. to 90° E. longitude and from about 35° to nearly 70° S. latitude. The following key is based on the examination of 70 specimens of *nutrix* and *canaliculata*.

Key to the Species.

Actinal primaries not conspicuously flat, trowel-shaped, and entire.

Median ambulacral and interambulacral areas bare and more or less deeply sunken; interambulacral area usually with a conspicuously deep vertical furrow; vertical diameter about .55–.60 h. d.; abactinal system and actinostome rather small, .35–.40 h. d., about equal, or former smaller . . . . *canaliculata*

Median ambulacral and interambulacral areas little bare, and not at all sunken; vertical diameter about .45–.55 h. d.; abactinal system and actinostome large, about .50 h. d., about equal or former larger . . *nutrix*

Actinal primaries conspicuously flat, trowel-shaped, and entire; primaries long . . . . *mortenseni*

Austrocidaris canaliculata.

Temnocidaris canaliculata A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Plate 1, g, fig. 2, Rev. Ech., A. Agassiz, 1873. Plate 2, figs. 1–3, Challenger Ech., A. Agassiz, 1881.

Some of the differences between this species and the next have already been set forth by Mortensen (:**03**), but he has entirely ignored the more important differences in the test and abactinal system. Moreover he has himself been led astray by the remarkable diversity which this species exhibits in its color, spines, and pedicellariae, and has described as a new species of Stereocidaris, which he calls *lorioli*, the long-spined form of *canaliculata*, which the "Challenger" collected off the mouth of the River Plate (Station 320). The Museum of Comparative Zoölogy contains one of the "Challenger" specimens from St. 320, and also a large

series of specimens from Patagonia. The latter so completely yet gradually connect the individuals having primaries 2.5 h. d. with those from the Falkland Islands in which the primaries are only .65 h. d., that their identity cannot be doubted. Had Mortensen carefully examined an interambulacrum, he probably would not have been misled. Although usually about 25–30 mm. h. d., there are specimens of *canaliculata* at hand 36 and 39 mm.; the primaries range from 16 to 63 mm. The color varies from very pale yellowish (with pink necks on the primaries) to very dark brown. This species is apparently confined to the eastern and southern coasts of Patagonia and the neighboring islands. The bathymetric range is from the shore to 600 fathoms. A specimen in the National Museum, which was obviously collected many years ago, is labelled "Navigator Islands."

Austrocidaris nutrix.

Cidaris nutrix Wyville Thomson, 1876, Journ. Linn. Soc. London, **13**, p. 62.

Fig. 4, p. 63, Journ. Linn. Soc. London, 13, Wyville Thomson, 1876.

There can be little question that this species is quite distinct from the preceding. Like it, however, it shows considerable diversity in color and the length of the primaries; some specimens are almost black, with light-colored primaries, while others have the test and secondaries, as well as the primaries, very light colored. Mortensen (:**03**) asserts, without offering any evidence to support his view, that the specimens collected by the "Challenger" at stations 147, 153 and 156 are not this species because the water was too deep at those stations for a shallow water species like *nutrix*. In view of the fact that a number of echinoderms are known with a very great bathymetric range, we can hardly consider the argument conclusive. The largest specimen of *nutrix* at hand is only 30 mm. h. d., but the primaries are 66 mm., while a specimen 26 mm. h. d. has primaries only 18 mm. This species appears to be confined to Crozet, Heard, and Kerguelen Islands, and the neighboring seas.

Austrocidaris mortenseni.

Goniocidaris mortenseni Koehler, 1902, Belgica Ech. et Oph., p. 5.

Figs. 1, 11, 17, 29, 30, Belgica Ech., Koehler, 1902.

It is quite possible that this species does not belong here, but so far as can be judged from the description and figures given it is most nearly allied to the foregoing species. Koehler says nothing about the secondaries, and as the primaries are very long, it is possible that the secondaries are not especially peculiar. The largest specimen was 26 mm. h. d., with primaries 60 mm. The color of the test and secondaries is very dark, while the primaries are reddish. Koehler says there was no indication that the species is "viviparous," but as he only had a single mature specimen, and that possibly a male, further light is needed on this point. The specimens were collected by the "Belgica" in the Southern Ocean, near 70° S. latitude and 87° E. longitude, in depths of 55–330 fths.

CENTROCIDARIS.

Centrocidaris A. Agassiz, 1904, Pan. Deep Sea Ech., p. 32.

Test very flat, vertical diameter generally less than .50 h. d.; coronal plates 7 or 8; areolae very little sunken; median interambulacral areas narrow, a little sunken, and bare; ambulacra very broad, .55–.60 of interambulacra; poriferous zones little or not at all sunken; median ambulacral area broad, flat, or somewhat depressed, with a double marginal series of tubercles, outer much larger; intervening space bare, or each ambulacral plate may carry an additional miliary tubercle; pores very large, nearly or quite horizontal; distance between two about equal to diameter of pore; surface of interval slightly elevated. Abactinal system moderate, .45–.50 h. d., with few (about 100) tubercles; genital plates much higher than wide, narrow, and bluntly-pointed externally; oculars entirely excluded from anal system, very wide and low but sharply pointed, with a markedly concave outer margin. Actinostome, .40–.45 h. d. Primary spines straight, cylindrical, slender, and nearly or quite smooth, about equal to h. d. or somewhat longer; actinal primaries not peculiar save for a wide collar; secondaries flat, thin, and narrow. All three kinds of pedicellariae usually present; large globiferous ones of two quite distinct sorts, one with broad, flat valves and neither lip nor end-tooth, the other with curved valves (like Cidaris), but with a prominent end-tooth and lip.

This monotypic genus was established for a very interesting and handsome cidaroid taken by the "Albatross" in 1891 off Cocos Island, 52 fths. In 1904–05, the "Albatross" obtained a dozen additional specimens near Hood Island, Galapagos, 100–300 fths., so that it is now possible to diagnose the genus fully. It is quite distinct from Goniocidaris, though it resembles it in the broad ambulacra, but it is doubtful if it is nearer to any other known genus.

Centrocidaris doederleini.

Goniocidaris Doederleini A. Agassiz, 1898, Bull. M. C. Z., **32**, 5, p. 73.
Centrocidaris Doederleini A. Agassiz, 1904, Pan. Deep Sea Ech., p. 33.

Plate 14, figs. 1, 2, Pan. Deep Sea Ech., A. Agassiz, 1904.

In young specimens the primary spines are very white and shining, and have 8–10 slightly elevated, glassy, longitudinal ridges, but these practically disappear with age and the spines become dull and yellowish. In alcoholic specimens the secondaries are green, slightly tipped with dark yellow, while the test is greenish with the lines between the genital and ocular plates and the bare spaces of ambulacra and interambulacra deep purplish or dull red. The largest specimen is 28 mm. h. d. and the longest spines measure 33 mm.

APOROCIDARIS.

Aporocidaris A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 36.

Test flattened, .50–.60 h. d. (but abactinal system sometimes so much elevated that vertical diameter from centre of anal system, .60–.80 h. d.), rather thin and fragile; coronal plates 6, rarely 7; areolae only slightly sunken; median interam-

bulacral area rather wide, bare, and slightly sunken along sutural line; ambulacra about .30 of interambulacra; poriferous zones almost flush with test; ambulacral plates few, 30–32 in largest specimens; median ambulacral area somewhat wider than a poriferous zone; each ambulacral plate is vertically wide and carries only a single tubercle, except in large specimens, when a second smaller tubercle is present and then vertical suture is obscured; pores very close together, somewhat oblique. Abactinal system very large, .60–.70 h. d., either flat or more or less elevated, with few or many tubercles. Actinostome .40–.50 h. d., consequently only .60–.80 of abactinal system, and notable for small number of plates borne by membrane, more or less of which near outer margin is quite bare. Primary spines slender, straight, and cylindrical, very finely prickly, white or nearly so, 1.5–3 h. d.; actinal primaries either coarsely or finely serrate or entire; secondaries and miliaries alike, cylindrical or club-shaped, blunt and more or less erect, rather scattered. Pedicellariae of only one kind, globiferous, but very variable in size.

The affinities of this interesting genus are rather obscure, for although the secondary spines resemble those of *Austrocidaris nutrix*, it is hard to believe that there is any close relationship to that species. There are no other living species of Cidaridae which approach sufficiently near the three rare species placed here to give us any real clue to their natural position. Although *A. milleri* has actinal primaries similar to those of Porocidaris, there is little else to ally it with that genus, and the other two species are even more different. The large abactinal system, few ambulacral plates, unsunken poriferous zones, somewhat bare actinostome, and the primary spines are striking reminders of Salenia. Two of the species are discoveries made by the "Albatross" and are found only in the deep waters of the Pacific Ocean; although *milleri* was once taken in 465 fths., most of the specimens are from over 1,600 fths. and *fragilis* has been taken only at depths exceeding 1,500 fths. The third species was found by the "Belgica" in much shallower water, but in the far Antarctic Ocean. The following key is based on the examination of 116 specimens of the two "Albatross" species.

Key to the Species.

Test moderately high, .55 h. d. and more; abactinal system elevated, with numerous tubercles (250–300 on a system 13 mm. across); ambulacral plates about 20, in a specimen 15 mm. h. d. . . . . *milleri*

Test flat, about .50 h. d.; abactinal system not elevated, with comparatively few tubercles (100–200 on a system 13 mm. across); ambulacral plates about 15, in a specimen 15 mm. h. d.

Color reddish- or yellowish-brown; arctic . . . . *fragilis*

Color bay or reddish; antarctic . . . . *incerta*

Aporocidaris milleri.

Porocidaris Milleri A. Agassiz, 1898, Bull. M. C. Z. **32**, 5, p. 74.

Aporocidaris Milleri A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 37.

Plate 6, Pan. Deep Sea Ech., A. Agassiz, 1904.

The test of this species is grayish, sometimes with a purple tinge, or yellowish, and the secondaries are of about the same color or paler. The primaries are

nearly or quite white. The largest specimen is 31 mm. h. d., while the primaries are sometimes 75 mm. long. The abactinal system is often elevated 3 or 4 mm. above the test. The "Albatross" collected this species in 1891, in the deep water between Acapulco and Panama, and the Galapagos, 465–1880 fths., while in 1904–05 she found it common in the still greater depths south and southwest of the Galapagos, 2005–2153 fths.

Aporocidaris fragilis.

Aporocidaris fragilis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 37.

Plate 23, figs. 5–8, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

Of this species, the only known specimens, the largest of which is 23 mm. h. d., with primaries over 40 mm. long, were taken by the "Albatross" in the North Pacific, south of Alaska and southwest of Kamchatka in 1557–1973 fths.

Aporocidaris incerta.

Porocidaris incerta Koehler, 1902, Belgica Ech. et Oph., p. 7.

Figs. 2, 16, Belgica Ech., Koehler, 1902.

Koehler's supposition that this species is related to *milleri* is quite correct, though in the shape of the test it is more like *fragilis*. The position of *incerta* in this genus is confirmed not only by Mortensen's (:03) examination of the pedicellariae, but by a careful comparison of Koehler's description, with a specimen of *fragilis* of the same size (15 mm. h. d.) as his largest specimen. It is difficult to make out from that description just how much difference there is between the Arctic and Antarctic species. The latter was taken by the "Belgica" about 20 degrees south of Kerguelen Island, in 55–165 fths.

Stereocidaris.

Stereocidaris Pomel, 1883, Class. Meth. Gen. Ech., p. 110.

Test very similar to Dorocidaris, but usually flatter (.50–.60 h. d.), with fewer coronal plates (4–7, rarely 8 or 9) and relatively fewer primary spines (3–7, rarely 8, in each vertical series); that is to say, uppermost coronal plate without primary spine, and second often, third very rarely, similarly bare. Abactinal system large (.35–.55 h. d., usually about .50), often convex, and noticeably thick and stout, but this character varies much within a single species; abactinal miliaries and secondaries usually very small, but this character also varies much. Primary spines usually flaring at tip, or if tapering, provided at base with conspicuous buttress-like "wings"; "winged" primaries are usually noticeably compressed, but otherwise primaries are cylindrical. Globiferous pedicellariae, large and small, commonly lack a conspicuous end-tooth on valves.

This is the most poorly defined and unsatisfactory genus in the family, and yet the species contained in it have something about their general appearance which is distinctive and makes it possible to recognize them usually at a glance. They show considerable diversity in test, spines, and pedicellariae, and some individuals are strikingly like Dorocidaris. It is only when a considerable amount

of material is available for comparison that such individuals can be properly placed. Unfortunately in preparing the following key there have been available only five species, represented by 69 specimens, and it is probable that errors have crept in which might have been avoided had a larger series of specimens been available. However, Anderson's and Doderlein's descriptions and figures are sufficiently complete and accurate to make it possible to include their species. Döderlein's (:06) measurements and figures have been of the greatest help. The Japanese species need revision based on plenty of material, and it is possible that the three species here recognized will prove to be simply forms of a single species, as the differences between them are slight. All the recent species occur in depths of 40 fathoms or over, and all but one (*ingolfiana*) are found only in the Indo-Pacific region. A number of fossil species from the Cretaceous are referred to this genus. How Döderlein (:06) can lay great stress on the form of the pedicellariae in Stereocidaris and write without qualification "Grosse und kleinere globifere Pedicellarien ohne unpaaren Endzahn" (p. 102), is incomprehensible, for his own figures (Plates XXXVI and XXXVII) contradict the statement flatly. Had I examined no specimens, the study of Döderlein's figures would have satisfied me that the pedicellariae are no more reliable than the spines.

Key to the Species.

Actinostome very small, .20–.35 h. d., usually under .30 except in young specimens.

- Primary spines often more or less trigonal, but seldom with three conspicuous "wings" near base; tridentate pedicellariae wanting; pedicels contain perforated plates besides thorny curved rods.
  - Longest primary spines, 1.3–2.7 h. d., thickness commonly less than 8% of length; perforated plates in pedicels small, with few large holes . . . . *indica*
  - Longest primary spines about 1.35 h. d., thickness about 10% of length; perforated plates in pedicels broad, with many small holes . . . *capensis*
- Primary spines commonly with three conspicuous wings near base; tridentate pedicellariae common; pedicels with few or no perforated plates . . . . *tricarinata*

Actinostome larger, almost always over .35 h. d.

- Primaries pale pink or reddish, with 10–16 longitudinal series of fine prickles, which often merge into ridges, and 1 (or more) of these becomes a conspicuous "wing" or "buttress" on basal half of spine, which is also often flattened; primaries tapering towards tip; coronal plates 5 or 6 (rarely 7).
  - Abactinal system coarsely tubercled; median ambulacral area depressed and bare along vertical suture, each plate with only 1 or 2 tubercles; color of test and secondaries madder purple . . . *alcocki*
  - Abactinal system with numerous small tubercles; median ambulacral area not depressed, often elevated along vertical suture, which is seldom visible, crowded with tubercles, each plate with 4–6; color of test and secondaries brownish, usually very pale; no tridentate pedicellariae . . . . *ingolfiana*

Primaries cylindrical, at least near base, never provided with "wings," but with more or less evident, longitudinal series of rounded or sharp granules, tending to become ridges near tip of spine, which is often flaring.

Ambulacra very narrow, only .18–.25 of interambulacra, not deeply sunken; median area closely covered with 6 series of tubercles; all miliaries very minute; neck of primaries white . . *microtuberculata*

Ambulacra .25–.33 of interambulacra in width.

Secondaries not white; actinostome much smaller than abactinal system; tridentate pedicellariae present.

Abactinal system elevated 10% or more above test; abactinal surface appears very bare from small, wide, closely appressed miliaries; primaries not white with purple collar . . . . *grandis*

Abactinal system flat or little elevated; abactinal surface well covered with ordinary miliaries; primaries when perfectly clean, white, usually with a distinct purple collar . . . *leucacantha*

Secondaries white or whitish; actinostome nearly equal to abactinal system; no tridentate pedicellariae . . . . . . *sceptriferoides*

Stereocidaris indica.

Stereocidaris indica Döderlein, 1901, Zoöl. Anz., **23**, p. 19.

Plate 10, figs. 1, 2; Plate 11, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

This species appears to be very variable, and Döderlein (:**06**), recognizes four varieties (*integra*, *africana*, *carinata*, *sumatrana*), based upon slight differences chiefly in primary spines and pedicellariae. He says, however, that he doubts the constancy of any of these varieties except *sumatrana*, which appears to be well-marked. Döderlein's admirable descriptions and his tables of measurements are all that could be desired, but the figures given often suffer from indistinctness; they are quite good enough, however, to reveal the notable diversity in the pedicellariae of this species. The color is yellowish, each of the larger secondaries with a dark spot and the actinal primaries white. The largest specimen measured 46 mm. h. d. The distribution of *indica* is from Somali-Land to the Moluccas, in 443–715 fths.

Stereocidaris capensis.

Stereocidaris indica var. *capensis* Döderlein, 1901, Zoöl. Anz., **23**, p. 19.
Stereocidaris capensis Döderlein, 1906, Deutsche Tiefsee Exp. Ech., p. 110.

Plate 10, figs. 3–6, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

Although closely related to the preceding species, Döderlein considers the South African form entitled to specific rank. As he finds the chief and most constant character in the calcareous plates of the pedicels, the species seems to me open to serious doubt, for I do not consider that any importance can be attached to the exact form of the microscopic, calcareous particles of the Echini. The only known specimens of *capensis* were taken by the "Valdivia"

off Cape Colony in 278 fths. The largest measured 36 mm. h. d. The color is gray, with a brownish tinge, the secondaries with darker tips, and the actinal primaries whitish.

Stereocidaris tricarinata.

Stereocidaris indica var. *tricarinata* Döderlein, 1901, Zoöl. Anz., **23**, p. 20.
Stereocidaris tricarinata Döderlein, 1906, Deutsche Tiefsee Exp. Ech., p. 112.

Plate 9, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

This species seems to be rather better defined than *capensis,* but as its validity depends largely on the value assigned to certain features of the pedicellariae, there is still room for some doubt as to its proper standing. The deformed specimen to which Döderlein has given the varietal name *teretispina* is indeed very different from the typical form, but as it was a parasitized individual, its peculiarities may be pathological. The "Valdivia" collected *tricarinata* only in the vicinity of Sumatra in 206-417 fths. The largest specimen was 54 mm. h. d. The color of the test is dark reddish; the primaries are gray with rosy necks; the actinal primaries whitish; the larger secondaries have a dark spot.

Stereocidaris alcocki.

Dorocidaris alcocki Anderson, 1894, Journ. Asiat. Soc. Bengal, **63**, pt. 2, 3, p. 191.

Plate 5, figs. 3, 3a, Ill. Investigator Zoöl. Ech., Alcock and Anderson, 1895.

There can be little question of the validity of this species unless *indica* proves to be even more variable than is supposed. If the published descriptions are accurate (and there is no apparent reason for doubting them), the two species are quite distinct. The "Investigator" took *alcocki* in the Laccadive Sea in 636 fths. It is a small species, only 25–26 mm. h. d.

Stereocidaris ingolfiana.

Stereocidaris ingolfiana Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 38.

Plate 6, figs. 1–5, 11, Ingolf-Exp. Ech., Mortensen, 1903.

It is rather curious that this very distinct and interesting species should not have been described until so recently, for adult specimens are easily distinguished from any other North Atlantic or West Indian species. Even when the primary spines are missing or do not have the "wings" developed, the species may be recognized by the very numerous slender secondaries and miliaries, and the more or less elevated median ambulacral area, densely covered with minute tubercles. Mortensen's description lacks nothing, but in the table of measurements it is evident that "height" is estimated in some variable way; for while in a large series of tests of such a variable species as *D. papillata,* for example, there is sometimes a variation of 20% in the vertical diameter, Mortensen's measurements would indicate a variation of 30% among 8 specimens of *ingolfiana;* and while *papillata* is occasionally .75 h. d. in height, Mortensen gives one speci-

men of *ingolfiana* over .90 h. d., or, in other words, almost spherical! The specimens in the Museum of Comparative Zoölogy are .54–.58 h. d., while Mortensen's table gives .61–.91 h. d. as the range for his 8 specimens; it can hardly be doubted that this difference is due to the method of measurement used. In the diameter of the abactinal system and the actinostome, Mortensen's figures, .41–.54 h. d. for the former and .36–.40 h. d. for the latter, accord well with the measurements of the specimens in the Museum of Comparative Zoölogy. One error in his table occurs which may be either a slip of the pen or a misprint; the specimen 28 mm. h. d. is said to have the abactinal system only 10.5 (the same as the actinostome), while examination of the figure given on Plate 6 (which is apparently that specimen) shows the abactinal system to be about 14 mm., which is what would be expected. The largest specimen recorded is 35 mm. h. d.; the color is brownish, but not at all distinctive. The geographical range is from Iceland to Nevis, in 165–665 fths.

Stereocidaris microtuberculata.

Cidaris (*Stereocidaris*) *microtuberculata* Yoshiwara, 1898, Ann. Zoöl. Jap., **2**, pt. 2, p. 57.

Plates 1 and 2.

Although this species is closely allied to the following, it is easily distinguished by the characters given in the key. The test and small spines are yellowish-brown with a greenish tinge, and the larger secondaries have a median, longitudinal stripe of a darker shade. The fully developed primaries, when clean, are white. This is the biggest member of the genus, the diameter of the largest known specimen being 86 mm.

Stereocidaris grandis.

Dorocidaris grandis Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 77.
Stereocidaris grandis Döderlein, 1887, Jap. Seeigel, p. 42.

Plate 1, Plate 2, figs. 1–11, Jap. Seeigel, Döderlein, 1887. Plates 33, 36, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

The series of specimens at hand from Japan and Hawaii shows that this is a well-characterized but somewhat variable species. The primaries are quite stout (the thickness 5–7% of the length), usually deep pinkish, especially at base, but often brown, gray, or green, while the test is gray, yellowish, or greenish, and the secondaries yellowish or greenish, often with a broad, longitudinal green stripe; the general effect is greenish, more or less inclined towards yellowish. The largest specimen in the series is 40 mm. h. d., but Döderlein's largest specimen was 61 mm. Specimens of *grandis* are known not only from Japan and Hawaii, but also from the Dutch East Indies (de Meijere: **04**). It is possible that those to which de Meijere refers as having "die Halse" "hell violet" are really to be referred to the next species.

Stereocidaris leucacantha.

Stereocidaris leucacantha A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 23.

Plates 15, 32, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

Although this Hawaiian species, collected at a number of stations by the "Albatross," is very close to *grandis* in many ways, the two are easily distinguished at a glance, and no intermediate specimens have been seen. The largest specimen is 57 mm. h. d. The color is somewhat variable, that of the test and secondaries ranging from almost yellowish-white to deep purplish-gray; there is usually a decidedly purple cast actinally. The primaries are longer and more slender than in *grandis* (the thickness only 4 or 5% of the length), and are white when clean. The fully grown ones almost always have the collar deep purple, sharply contrasted with the white neck. In many specimens the secondaries show an evident green tinge.

Stereocidaris sceptriferoides.

Cidaris (*Stereocidaris*) *sceptriferoides* Döderlein, 1887, Jap. Seeigel, p. 5.
Stereocidaris sceptriferoides Döderlein, 1887, Jap. Seeigel, p. 42.

Plate 2, figs. 12–17, Jap. Seeigel, Doderlein, 1887.

This species, although it appears to be very rare, is well characterized. The globiferous pedicellariae are very slender, the valves often have a conspicuous end-tooth, and the opening may be very long and narrow. The only known specimens of this species were taken in Japanese waters.

ANOMOCIDARIS.

Anomocidaris A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 30.

Test rather flat, vertical diameter about .50 h. d., but sometimes, through elevation of abactinal system, conspicuously rounded-conical; vertical diameter from centre of anal system in such cases being about .60 h. d.; coronal plates 7–9; areolae abactinally small, very shallow and indistinct, on the uppermost plates practically wanting, but at ambitus and below deeply sunken and merging together near actinostome; median interambulacral area covered with small tubercles, not at all bare or sunken, but sutural lines distinct; ambulacra about .30 of interambulacra; poriferous zones not deeply sunken; median ambulacral area with two or three series of tubercles on each side, inner much smaller and more or less incomplete; vertical sutural line usually distinct; pores nearly horizontal; distance between two not quite equal to diameter of pore. Abactinal system moderate, about .47 h. d.; anal system small, less than .40 of abactinal system and composed of only about 20 plates and grains; oculars rather small and genitals very widely in contact with each other. Whole abactinal surface more or less densely covered with very small secondaries, miliaries, and pedicellariae. Actinostome small, .35 h. d., only about .75 of abactinal system. Primary spines slender, 1–1.50 h. d.; thickness 3–5% of length; cylindrical with longitudinal series of minute granules, sometimes nearly smooth, often flattened and widened at tip; actinal primaries very variable, some-

times flattened, curved, and entire, slightly notched or even serrate, but frequently thick, straight, and more or less smooth; secondaries flat, those on ambulacra quite narrow. Large globiferous sometimes, and tridentate pedicellariae always, wanting; small ones sometimes with, more often without, end-tooth on valves.

The above diagnosis of this interesting monotypic genus is based on a large series of specimens, 11–40 mm. h. d., which admits of little question of the identity of Döderlein's *St. japonica* and Yoshiwara's *C. tenuispinus.* Some of the peculiarities are given by those writers in their original descriptions of the only species, which they regarded as a Stereocidaris. While its nearest relatives are probably to be found in that genus, it is quite distinct from them and is well entitled to generic rank. For a full discussion of this genus and its type species, see A. Agassiz and Clark, 1907, Bull. M. C. Z., **51**, p. 112–114.

Anomocidaris japonica.

Dorocidaris japonica Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 76.
Stereocidaris japonica Döderlein, 1887, Jap. Seeigel, p. 34.
Cidaris (*Stereocidaris*) *tenuispinus* Yoshiwara, 1898, Ann. Zoöl. Jap. **2**, pt. 2, p. 57.
Anomocidaris tenuispina A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 30.
Anomocidaris japonica. A. Agassiz and Clark, 1907, Prelim. Rep. Albatross 1906 Ech., Bull. M. C. Z., **51**, p. 112–114.

Plate 31, figs. 5–8, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907. Plate 3, Jap. Seeigel, Döderlein, 1887.

The only known specimens of this species have been taken in Japanese waters, in 40–284 fths. The largest specimen is 40 mm. h. d. The color of test and secondaries is commonly some shade of brown, often reddish, sometimes greenish, while the primaries are grayish or brownish, often with a decidedly olive-green tinge, rarely rosy-reddish; the neck is brown, usually polished and shining.

ACANTHOCIDARIS.

Acanthocidaris Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 21.

Test high, .60–.70 h. d.; coronal plates 7 or 8; areolae not at all sunken and very distinct, even actinally; median interambulacral area somewhat sunken and bare along vertical suture; ambulacra about .25 of interambulacra; poriferous zones little sunken; each ambulacral plate slightly curved, with a single large tubercle near upper margin of median portion, a much smaller one near lower margin halfway to inner end, and a very minute one (which usually carries a pedicellaria) just beneath largest; this arrangement is remarkably constant, regardless of age and size; it is well shown in a specimen 9 mm. h. d., and is not essentially different in one 52 mm. h. d.; in some very large specimens, however, another small secondary tubercle may be borne on inner end of plate; median vertical suture usually visible, but there is no noticeable median bare strip; pores oblique much as in Cidaris. Abactinal system about .45 h. d., very flat; peculiar in that all oculars are broadly

in contact with anal plates except right anterior one; this ocular is wholly or very nearly excluded; instead of being an individual peculiarity (as sometimes occurs in Tretocidaris *et al.*), this curious arrangement is remarkably constant, and is as evident in a specimen 17 mm. h. d. as in those over 40 mm. Actinostome .35–.40 h. d., generally about .90 of abactinal system. Primary spines unique, 2.5–3.3 h. d., straight or somewhat curved, nearly smooth; base broad and depressed, somewhat triangular in cross-section, with more or less evident traces of longitudinal series of granules, but in large specimens these are scarcely visible; collar enormously wide, .20 or more of length of spine, and abruptly contrasted with remainder in color; this remainder bears 10–20 sharply distinct longitudinal ribs, which are seemingly continuations of series of granules on collar; outer limit of collar not straight, *i. e.* forming a ring around spine, but more or less deeply concave on both sides, especially actinally; tip of primary blunt or more or less expanded; actinal primaries conspicuously capped and serrate as in Stephanocidaris, but much stouter than in that genus; secondaries long, slender, and flat. All three kinds of pedicellariae present; globiferous, both large and small, lack an end-tooth on valves; stalks of large ones usually with a "limb."

This notable genus will be recognized at first sight by the peculiar, handsome spines somewhat resembling those of Coelopleurus. The above diagnosis is based upon the examination of fifty fine specimens of *hastigera*, representing all ages. The type of the genus is the species named by Bell ('93) *curvatispinis*, but nothing is known of its test or abactinal system, for neither Bell nor Mortensen (: 03) has attempted any description beyond spines and pedicellariae. It is interesting to find that the "Siboga" collected in the East Indies a third species of this genus, which de Meijere (: 04) has named *Cidaris maculicollis*. His careful description of the primary spines leaves no doubt as to the proper relationship of this new form, although the describer, in spite of the primaries, places it in the same subgenus with *C. metularia*, *tribuloides*, etc., because he considers the large globiferous pedicellariae like those of Cidaris. As a matter of fact, however, the valve of a pedicellaria which de Meijere figures is quite as near Acanthocidaris as it is to typical Cidaris. On account of the broad collar and the serrate actinal primaries, de Meijere (: 03) originally described *maculicollis* as a Porocidaris, but it really has as little in common with that genus as with Cidaris.

Key to the Species.

Collar of primary spines very light-colored, unspotted; remainder of spine reddish or brownish.
- Secondaries cream-color or yellowish; base of primaries with distinct angles, which may be somewhat serrate . . . . *curvatispinis*
- Secondaries dark reddish-brown; base of primaries with rounded angles, not in the least serrate . . . . *hastigera*

Collar of primary spines greenish, with red spots; remainder of spine whitish with 3 or 4 cross-bands of reddish . . . . *maculicollis*

Acanthocidaris curvatispinis.

Cidaris curvatispinis Bell, 1893, Trans. Zoöl. Soc., London, **13**, p. 303.
Acanthocidaris curvatispinis Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 29.

Plate 38, Trans. Zoöl. Soc. London, 13, Bell, 1893.

Nothing is known in regard to this species, except that Bell has figured the entire animal and Mortensen the pedicellariae. The type specimen in the British Museum, and a second specimen in Paris, are both from Mauritius and are the only ones known. The type specimen is about 50 mm. h. d., with primaries 150 mm. long; many of the latter are banded near the tip with brownish and yellowish.

Acanthocidaris hastigera.

Acanthocidaris hastigera A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 39.

Plates 37–42, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

In addition to the differences mentioned above, this species may be distinguished from the preceding by the stouter primaries and their entire lack of any cross-barring or bands of color. It was found by the "Albatross" to be common among the Hawaiian Islands. When cleaned, the test is nearly white in young specimens, with the median ambulacral area red, the actinostome decidedly green, and the abactinal system dull greenish-red; in older specimens the white is replaced by reddish-cream color, and there is little green evident anywhere. When uncleaned the test is, like the secondaries, dark brownish-red, much lighter in very young specimens. The largest specimen is 52 mm. h.d.; the longest primaries are 145 mm. All of the "Albatross" specimens were taken on sandy bottom in comparatively shallow water, 23–222 fths.

Acanthocidaris maculicollis.

Porocidaris maculicollis de Meijere, 1903, Tijdsch. Ned. Dierk. Vereen. (2) **8**, p. 1.

Plate 3, figs. 18, 19, Siboga-Exp. Ech., de Meijere, 1904.

The secondaries of this species are described as having "a dark longitudinal stripe," but the ground color is not mentioned. The four specimens collected by the "Siboga" were all small (10–18 mm. h. d.) and were evidently young ones. They were taken at depths of only 39–53 fths., and at each of the three stations mussel-shells formed a characteristic feature of the bottom.

POROCIDARIS.

Porocidaris Desor, 1854, Syn. Ech. Foss., p. 46.

Test rather high, .60–.75 h. d.; coronal plates, 7–9; areolae more or less sunken and merging actinally; median interambulacral area with vertical sutural region somewhat sunken and bare; ambulacra .18–.34 of interambulacra; poriferous zones very little sunken; median ambulacral area with a single marginal row of tubercles,

and even this may be incomplete in small specimens; between are more or fewer scattered tubercles, but there is never a complete second series even in very large specimens; vertical sutural line, bare; pores oblique, close together, surface of interval rough or elevated. Abactinal system variable in size, oculars and especially genitals with noticeably wide bare margins. Actinostome .30–.45 h. d., with few or no interambulacral plates. Primary spines, when fully developed, long, 1.5–4 h. d. cylindrical or nearly so, white (sometimes tinged with rose, purple, or yellow) with a darker collar; actinal primaries flat, somewhat curved, coarsely and sharply serrate; secondaries flat and not peculiar. No globiferous pedicellariae whatever; tridentate pedicellariae very variable in size (.30–6.0 mm.) and form, with 2–4 (generally 3) unusually stout, wide valves.

This is one of the most distinct and easily recognized of the genera of recent Echini, but the species it contains are most perplexing and are exceedingly difficult to distinguish from each other. The genus has a wide geographical range, as it occurs in the North Atlantic Ocean, the Caribbean Sea, among the Galapagos Islands, the Hawaiian Islands, the East Indian Islands, and the Nicobar Islands, along the coast of Japan, near Australia, and along the east coast of Africa, it depths ranging from 169 to 799 fths. Several species from the Tertiary have been named, and serrate spines, like the actinal primaries of Porocidaris, occur in the Jurassic. There is little diversity of color in the genus, for the test, the collar of the primaries, and the small spines are commonly some shade of brown, often becoming very dark or deep purple with age, while the primaries are usually very white. The following key is based on the examination of 54 specimens representing all the species, except *misakiensis*.

Key to the Species.

Pedicellariae all with 2 valves . . . . *purpurata*

Pedicellariae mostly with 3 valves.

Abactinal system .40–.55 h. d.; primaries rather stout (thickness of large ones 3–6% of length), finely and sharply thorny. (These prickles are not always easily seen with the unaided eye, but are so distinct that a spine cannot be drawn upward between thumb and finger when lightly closed upon it.)

Small spines in interambulacra, outside scrobicular circles, above ambitus, very few; ambulacra almost wholly bare between marginal rows of tubercles; primaries stout, 1.5–2.5 h. d. (thickness 5–6 per cent of length), often becoming larger and fluted near tip, with numerous (25–30) longitudinal series of prickles . . . . . . *sharreri*

Small spines more numerous on upper half of test; ambulacra usually with scattered tubercles; primaries somewhat less stout, with about 12–15 longitudinal series of prickles, more or less tapering and never enlarged and fluted at tip, but occasionally with large projecting thorns near base.

Primaries less stout (thickness 3–4 per cent of length); no special depression on inner surface of valves of large pedicellariae above hypophysis; test, secondaries, and collar of primaries light reddish- or yellowish-brown . . . . *elegans*

Primaries stouter (thickness about 4.5 per cent of length); a distinct triangular impression on inner surface of valves of large pedicellariae above hypophysis; test, secondaries, and collar of primaries deep, dark brown . . . . *misakiensis*

Abactinal system .35–.45 h. d.; primaries very long and slender, 2.5–4 h. d. (thickness only 2–3 per cent of length); very nearly smooth (slip easily between thumb and finger).

Large pedicellariae always with 3 valves, which are distinctly pointed; anal system about .50 of abactinal; median ambulacral area about .37 of ambulacrum; size small, under 35 mm. h. d.; color pale, and primaries very white and shining . . . . *cobosi*

Large pedicellariae very variable, sometimes with only 2 or with 4 valves, which are usually broad and are rounded at tip; anal system about .45 of abactinal; median ambulacral area about .50 of ambulacrum; size large, up to 85 mm. h. d.; color usually very dark and primaries yellowish . . . . *variabilis*

Porocidaris purpurata.

Porocidaris purpurata Wyville Thomson, 1872, Ann. Mag. Nat. Hist., (4) **10**, p. 302.

Plate 59, Porcupine Ech., Wyville Thompson, 1875.

One needs only to compare a specimen of this cidaroid with any other member of the genus to reject Mortensen's (:03) proposed genus "Histocidaris," for aside from the pedicellariae, the only feature in which *purpurata* differs noticeably from the others is the presence of an exceptionally wide collar on *some* of the primaries of *some* specimens, and that can hardly be considered a very useful character. Moreover Mortensen's proposed variety *talismani*, which he thinks may even be a distinct species, cannot be recognized, for the primaries with swollen, fusiform, violet collars occur in typical *purpurata*, and one is figured by Thomson ('75), though they are not present in all specimens. The small spines and some of the abactinal primaries are light reddish- or purplish-brown. The largest recorded specimen is 50 mm. h. d. This species is known only from the North Atlantic, save for the specimen from the Nicobar Islands, collected by the "Valdivia," and referred to *purpurata* by Döderlein.

Porocidaris sharreri.

Porccidaris Sharreri A. Agassiz, 1880, Bull. M. C. Z., **8**, p. 71.

Plate 3, Blake Ech., A. Agassiz, 1883.

This handsome West Indian species was dredged by the "Blake" off Georgia in 279 fths. (in company with *St. ingolfiana*) and also near Barbados in 356 fths. The general color is red-brown and not at all purplish. The largest specimen is 69 mm. h. d., with spines 114 mm. long.

Porocidaris elegans.

Porocidaris elegans A. Agassiz, 1879, Proc. Amer. Acad., **14**, p. 198.

Plate 3, Challenger Ech., A. Agassiz, 1881.

Originally collected by the "Challenger" off New South Wales and southeast from the Philippines, specimens of Porocidaris, referred to this species, have since been taken by the "Valdivia" near Sumatra, and off the east coast of Africa, and by the "Siboga" among the Dutch East Indies. One of the specimens collected by the latter vessel measured 85 mm. h. d. The specimen from the Bay of Biscay reported by Koehler ('**96**) is doubtless not this species; but probably *purpurata*, though it might be *sharreri*, with which species *elegans* agrees in coloration and many other points. The 5 specimens taken by the "Siboga" which de Meijere (:**04**) calls "*Cidaris elegans juv.?*" are rather peculiar, especially the pedicellariae, and their real relationship is doubtful. The specimens taken by the "Valdivia" differ from *elegans*, not only in their remarkably light coloration, but in their small abactinal system, actinostome and anal system, the very thorny primaries, and their large number of coronal plates. It is quite likely that they are a distinct species.

Porocidaris misakiensis.

Cidaris (*Porocidaris*) *misakiensis* Yoshiwara, 1898, Ann. Zoöl. Jap., **2**, pt. 2, p. 58.

Plate 2, fig. 16, Siboga-Exp. Ech., de Meijere, 1904.

This is the most dubious species of the genus, especially as no complete description or figures have appeared. Aside from the original preliminary description, the only available information about *misakiensis* is contained in de Meijere's "Siboga" report (:**04**). He found one specimen which might be referred to this species, but the difference between it and *elegans* is difficult to understand, and it will be surprising if the two prove to be really distinct. Yoshiwara's specimen was 39 mm. h. d., and de Meijere's was 50 mm. The color is said to be dark brown.

Porocidaris cobosi.

Porocidaris cobosi A. Agassiz, 1898, Bull. M. C. Z., **32**, 5, p. 74.

Plate 9, Pan. Deep Sea Ech., A. Agassiz, 1904.

This is the handsomest species of the genus, and except *purpurata*, the easiest to recognize. It has been taken only once, and then by the "Albatross," near Chatham Island, Galapagos, on a rocky bottom in 385 fths. The largest specimen is only 35 mm. h. d.

Porocidaris variabilis.

Porocidaris variabilis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 32.

Plates 16–22, 23, figs. 1–4, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This species was found by the "Albatross" to be common among the Hawaiian Islands, and some very fine specimens were secured. The largest is deep purple, and measures 85 mm. h. d.; the others are various shades of brown, and one was very light-colored, like *cobosi*. It is possible that if *misakiensis* is really distinct from *elegans*, this species may prove to be identical with Yoshiwara's.

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1. Ambulacral view of partly cleaned specimen ; all primary spines broken.
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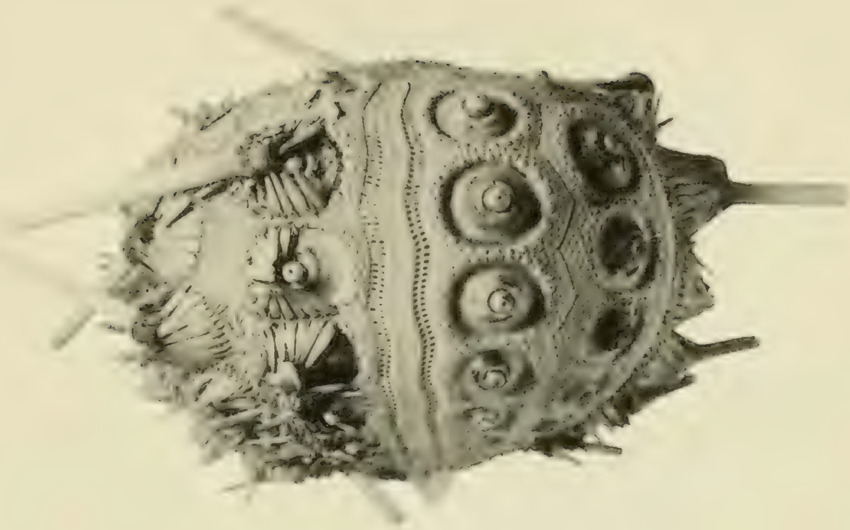

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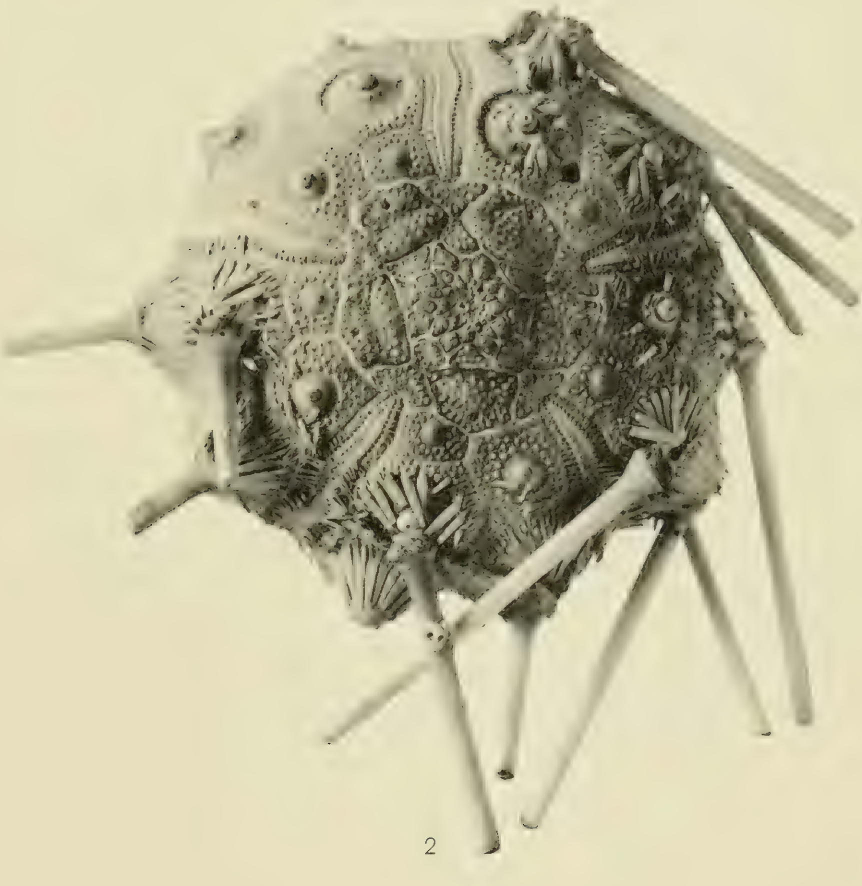

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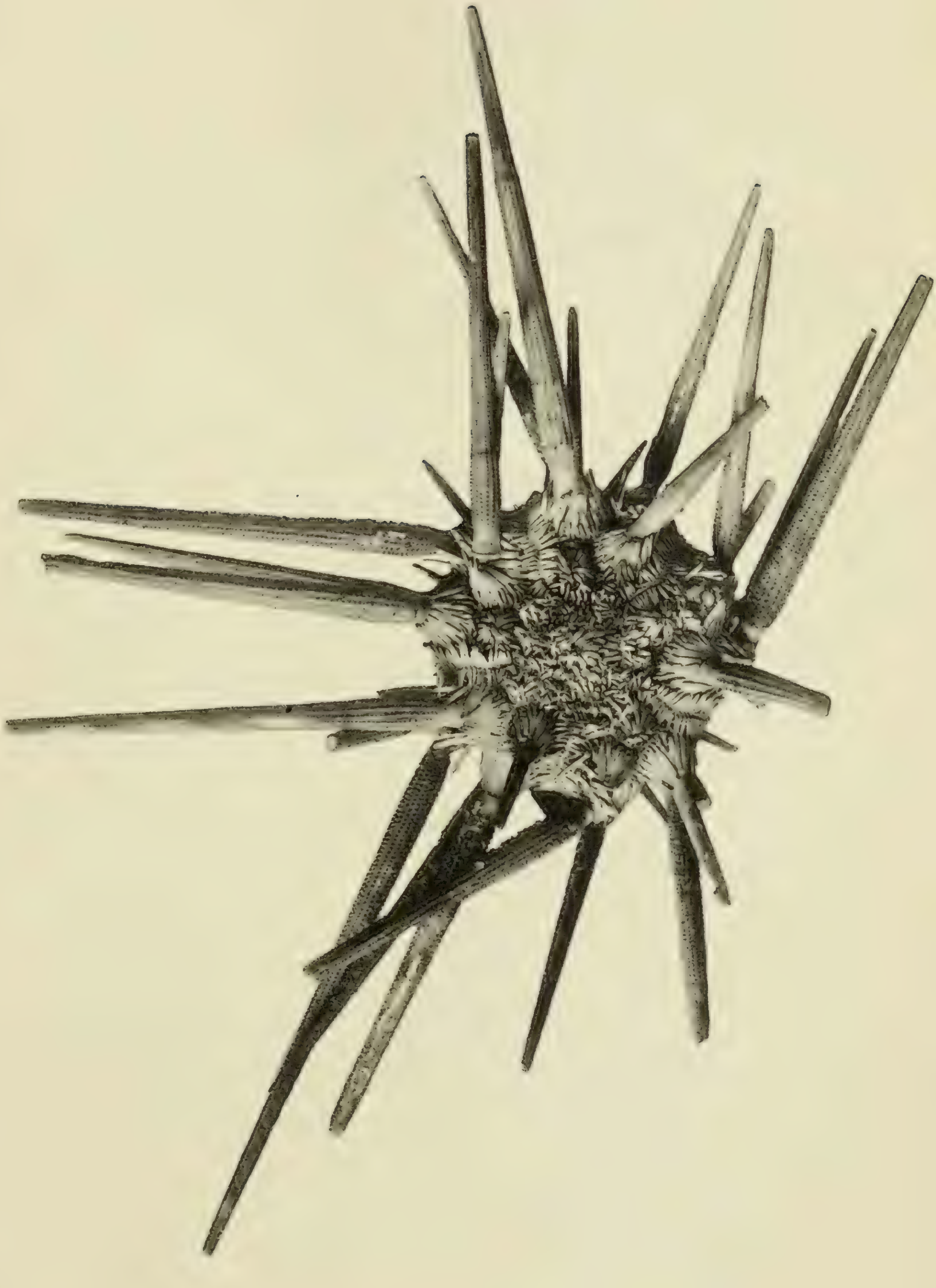
PLATE 4.

Dorocidaris rugosa, sp. nov. Nat. size.
Abactinal view.



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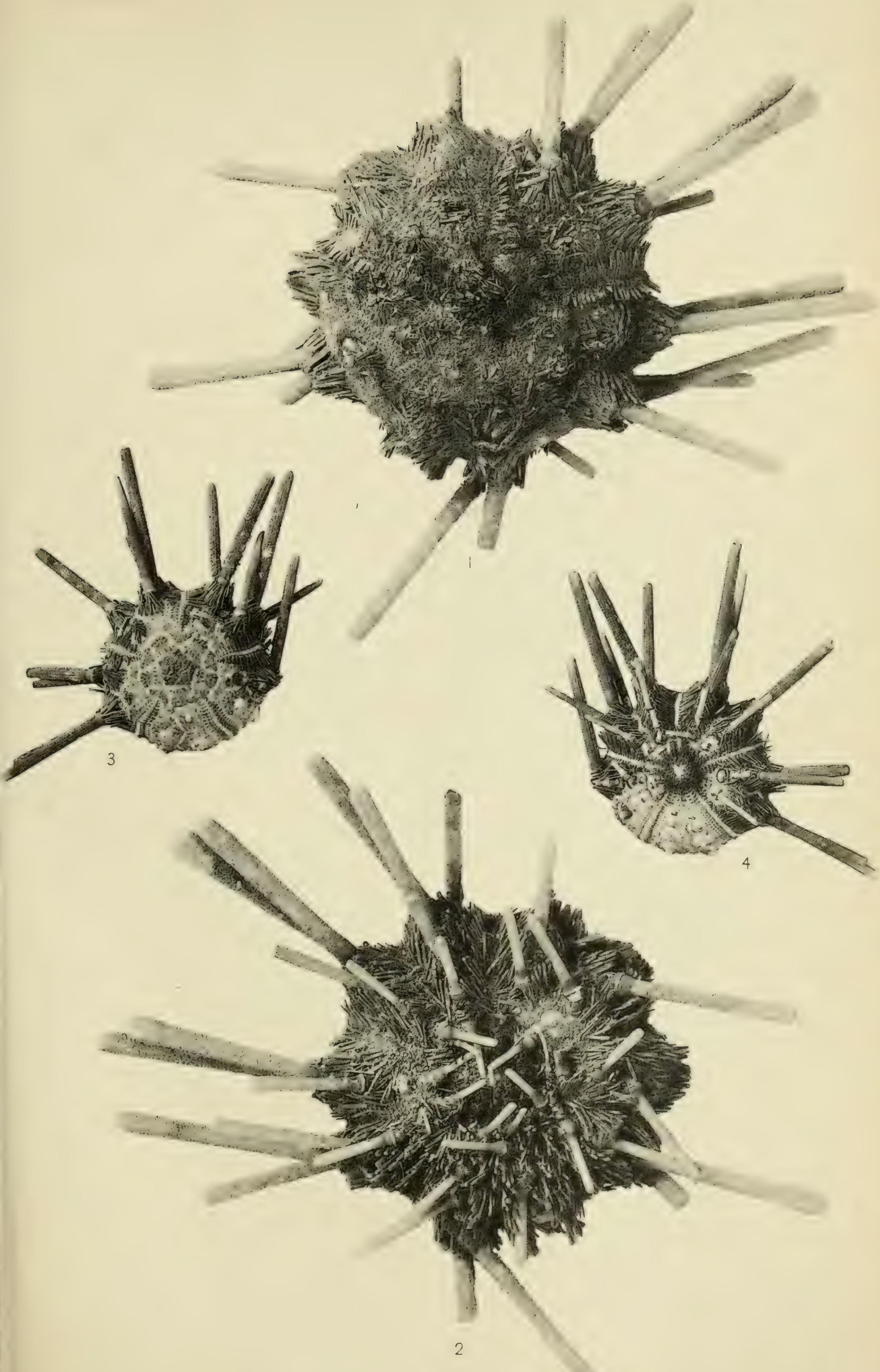
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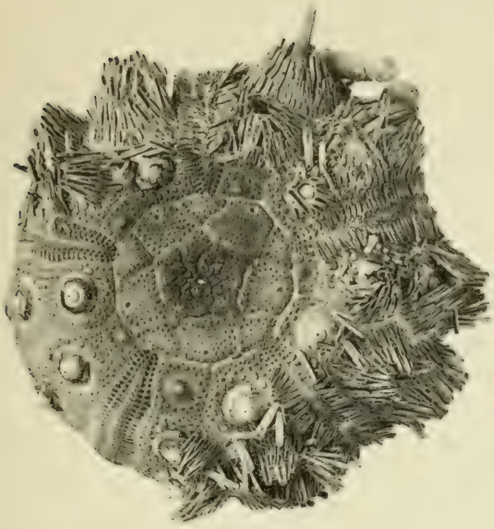

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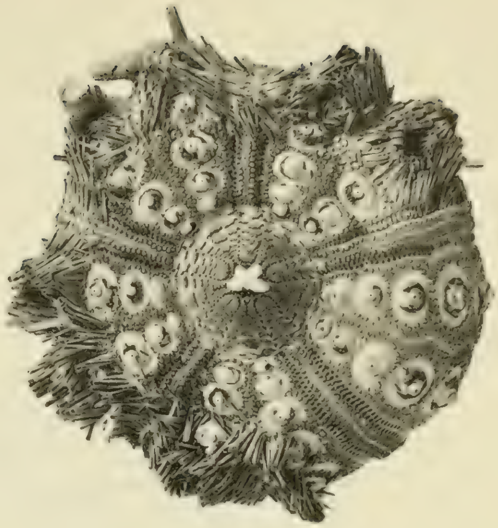

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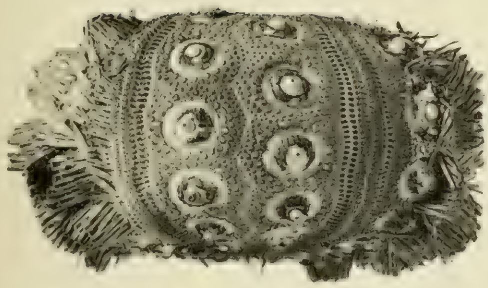

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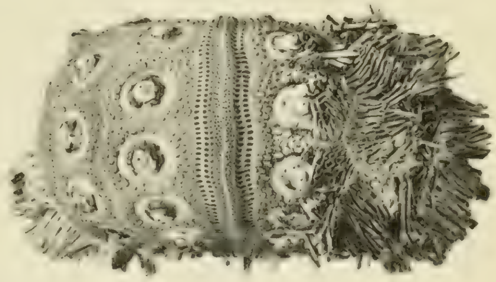

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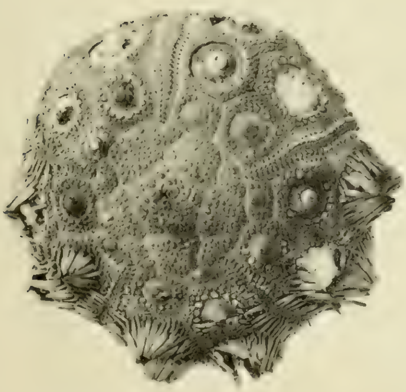

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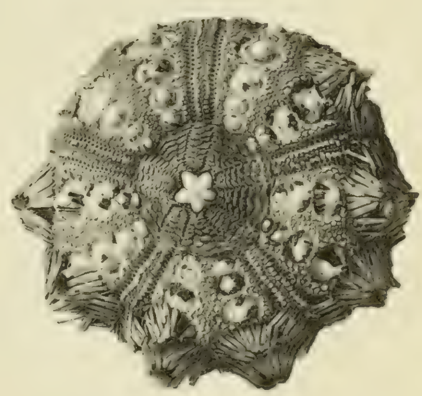

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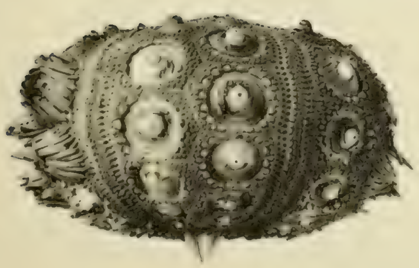

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PLATE 9.

Tretocidaris bartletti (A. Agassiz). Nat. size.
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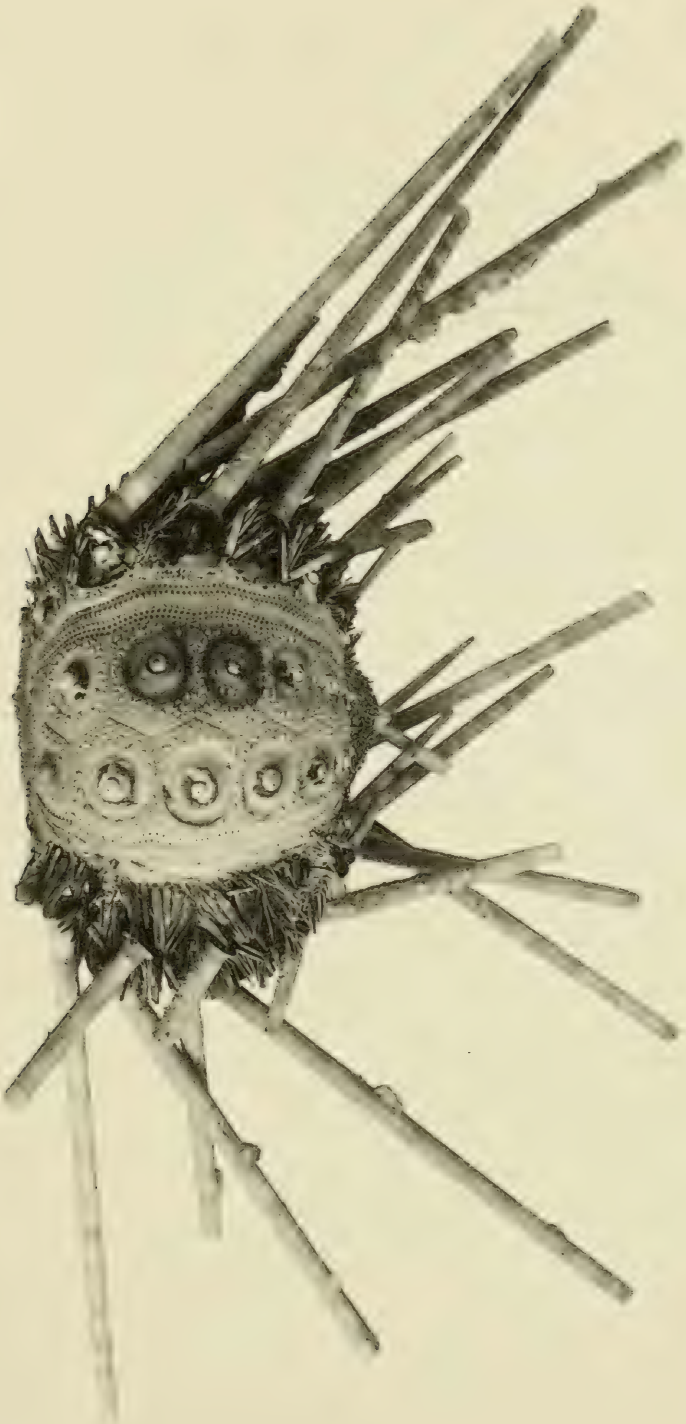

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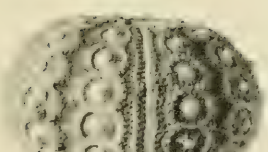

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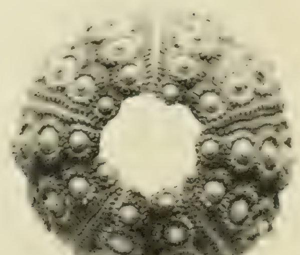

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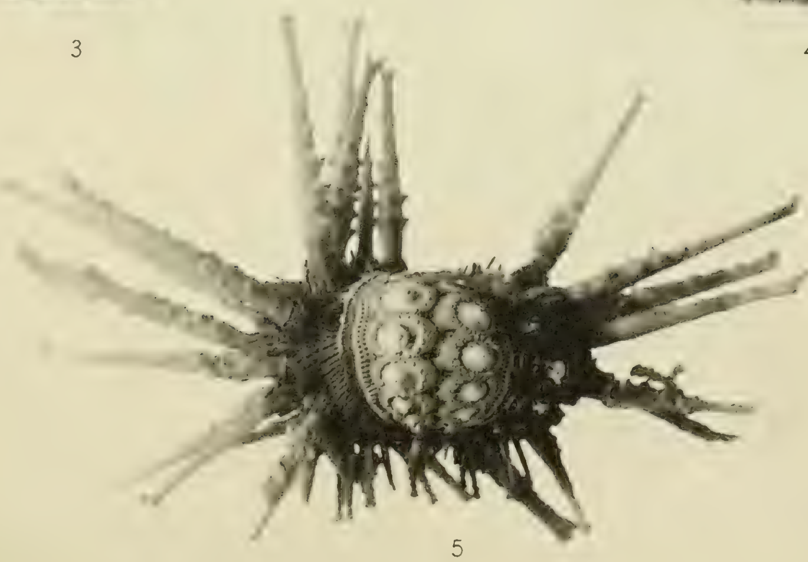

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PLATE 11.

Goniocidaris tubaria (Lamarck). Nat. size.

1. Abactinal view of partly cleaned, large specimen with short, stout spines.
2. Side view of same.

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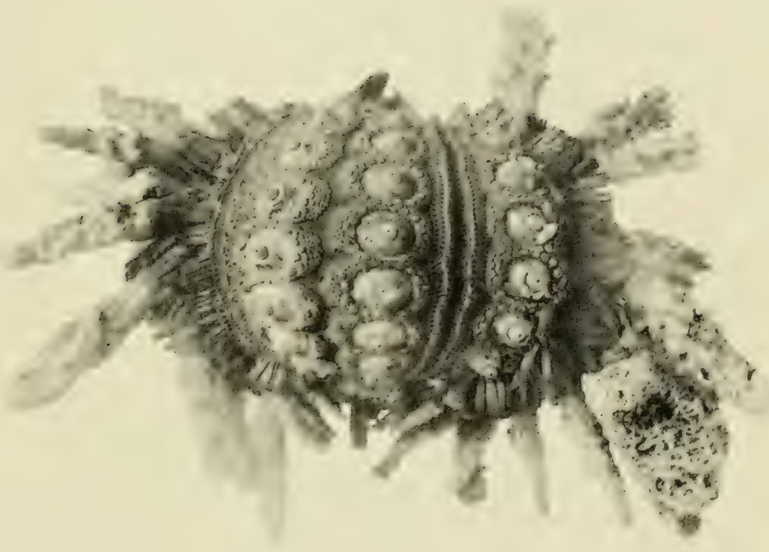

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Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. LI. No. 8.

NOTICE OF SOME CRINOIDS IN THE COLLECTION OF THE MUSEUM OF COMPARATIVE ZOÖLOGY.

By Austin Hobart Clark.

With Two Plates.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

January, 1908.

No. 8. — *Notice of some Crinoids in the collection of the Museum of Comparative Zoölogy.* By Austin Hobart Clark.

Two species of Crinoids were met with during the cruise of the "Albatross" in the eastern Pacific, one near the Central American coast, and the other approximately midway between the Marquesas Islands and Central America. The former, an unstalked form belonging to Heliometra, is represented by four specimens from three stations; the latter, a species of Bathycrinus, is represented by a single specimen without arms. The Bathycrinus, however, is a species of considerable interest, for not only does it greatly extend the range of the genus, which was hitherto known in the Pacific only from Kamchatka and southern Japan, but it presents a most extraordinary superficial resemblance to Rhizocrinus in certain of the characters of the stem and basals; so close, in fact, that the specimen was first recorded (Mem. Mus. Comp. Zoöl, 1906, **33**, p. 49) under that generic name, and a close examination under a microscope is necessary to reveal its true affinities.

Of the new species here described, *Heliometra juvenalis* calls for special mention. While undoubtedly closely allied to *H. eschrichtii*, it is remarkable in having prominent basals, cirri with less than twenty segments, and very short and stout lower pinnules, which are, in fact, much the shortest on the arms. The enlarged ovaries, however, containing ova, show that the specimens are adult, although the structure is that of very young specimens of other species of the genus. While no positive statement can be made on only two specimens, this seems to be a case of arrested development at a very early stage. Whether it is a permanent character or not must be left for future investigation; nothing similar is recorded, nor have I met with a similar case in my studies on the group.

STALKED CRINOIDS.

Bathycrinus equatorialis, sp. nov.

Radials and arms lacking.

Basals closely united into a smooth ring, slightly wider above than below, about as high as its greatest diameter; the sides of the ring are markedly convex, a character not known in any other species of Bathycrinus.

Stem 287 mm. long with ninety-two columnars ; the five columnars immediately following the basal ring are very thin and discoidal, the sixth thicker, the seventh about twice the height of the sixth; the following segments increase in length, the sixty-fourth being 4.25 mm. long and 1 mm. in diameter, and the ninety-second 4.90 mm. long by 1.75 mm. in greatest diameter. The columnars differ from those of all known species of Bathycrinus in being practically cylindrical until after the eightieth, when the articulations begin to be very slightly enlarged; but they are never markedly "dice-box shaped," as in the other species. In general the stem bears a striking similarity to the stems of Rhizocrinus, the more so as the thin discoidal segments at the summit are closely united so as to appear, on superficial examination, as a single piece, and I had some difficulty at first in deciding to which genus it belonged. The basal ring is large for Bathycrinus, but shows no sutures whatever, even under strong magnification, nor is there the slightest evidence of incorporated radials. The small number of discoidal segments at the summit of the stem also suggests Rhizocrinus, but in that genus there are never more than two which are broader than long, and usually only one; the topmost columnar in Rhizocrinus, moreover, is always considerably longer than are the very thin proximal columnars of Bathycrinus. Examination of the surface ornamentation of the basals and columnars shows the deep and confluent pitting peculiar to Bathycrinus, and not the fine, shallow, scattered indentations of Rhizocrinus.

As an item of interest it may be mentioned that the seventeenth, fifty-fourth, and fifty-fifth columnars have the axes of both faces in the same plane; the axes are normally at right angles to each other, although occasionally the angle of divergence is considerably less than 90°.

The rapid enlargement of the proximal columnars, together with their segregation into what appears superficially to be a single segment, and the cylindrical form of the majority suggest an interesting possibility in regard to the original figure of *Bathycrinus aldrichianus.* Of this figure Dr. Carpenter says: "The numerous thin joints immediately beneath the cup, which are so characteristic of the genus, are not properly represented in the woodcut, and the joints just below where these ought to be are considerably longer than one would expect to find so near the cup. It may be assumed that Mr. Wild's drawing was photographic in its accuracy, so far as he could make out the structure of the small specimen; but errors may have crept in during its reproduction on wood, and the cut was published during Sir Wyville's absence from England, so that he had no opportunity of revising it. Under these circumstances it appeared preferable to say nothing about the stem in the specific diagnosis given above rather than to attempt to describe it from a probably incorrect woodcut." While in *Bathycrinus australis, B. carpenterii,* and *B. pacificus* from twenty to twenty-five or even more of the proximal columnars are short and discoidal, in *B. gracilis* and *B. complanatus* the number is much reduced, being only about half as many or even less; in *B. equatorialis* only the first five are short enough to be comparable to the proximal segments in the other species, and from then on the length increases rapidly.

In *B. aldrichianus* the stem is represented as having only a single segment wider than high. Judging from *B. equatorialis,* this segment might easily have been three or four coalesced columnars appearing as a single one, and that following might have been in a similar condition. Even if this were not so, the stem structure of *B. equatorialis* throws a new light on the specific variation in Bathycrinus, and suggests strongly that the stem of *B. aldrichianus* as figured is in all essentials correct. At the time the species was dredged by the "Challenger," the only small stalked crinoids on board were five specimens of Rhizocrinus; as all of the five had the characteristic basals still attached to the stems, confusion with them is out of the question. In the same haul with *B. aldrichianus,* it is recorded that Hyocrinus stems were secured; but the stem as figured is certainly not that of a Hyocrinus. Sixteen days later Rhizocrinus was dredged again; but in this case also the basals were *in situ.* Four months later *Bathycrinus australis* and Hyocrinus were dredged; but the stem cannot be that of either of these. It was not until the last of February three years later that any more small stalked crinoids were found, too late for their stems to have become incorporated in the figure.

Type Cat. 22,664, U. S. National Museum, from "Albatross" Station No. 4742, 0° 3.4′ north latitude, 117° 15.8′ west longitude, 2320 fathoms, taken February 15, 1905.

Bathycrinus caribbeus, sp. nov

Radials and arms lacking.

Basals closely united into a smooth ring, slightly wider above than below, longer than wide, the sides perfectly straight.

Stem 85 mm. long with about one hundred segments, the proximal seven short and discoidal, then rapidly becoming longer, reaching a length of 1.3 mm. with a width of 0.4 mm. in the middle of the stem, the last segment being 2.8 mm. long by 1.2 mm. in diameter at its much expanded end. Above the middle of the stem the columnars are cylindrical; distally the articulations become more and more prominent and are greatly expanded on the last two segments.

While it is possible that the elongated basals and small number of short discoidal joints in this specimen are indications of immaturity, the completely anchylosed condition of the basals and the apparently full complement of columnars seem to show that this is not the case; and that the latter may be characteristic of much larger specimens we have just seen in the case of *B. equatorialis.*

Bathycrinus caribbeus forms an interesting addition to the crinoid fauna of the Caribbean Sea, the more so since the depth at which it was found is considerably less than the lowest previous record for the genus (*B. carpenterii* 743 fathoms), while the bottom temperature (40° F.) is remarkably high.

Type Cat. 22,665, U. S. National Museum, from "Albatross" station No. 2751, 16° 54′ 00″ north latitude, 63° 12′ 00″ west longitude, 687 fathoms; blue Globigerina ooze; bottom temperature, 40° F.

The discovery of four species of Bathycrinus since the publication of the

"Challenger" report makes a key to the species of the genus very desirable, especially since Dr. Carpenter in his key only included the three species discovered by the "Challenger" and the "Porcupine," omitting the interesting form dredged by the "Vøringen." In the preparation of the following key I have examined specimens of all the species given, with the exception of *B. aldrichianus*. There are two additional species as yet undescribed, one dredged by the "Valdivia" off Enderby Land, and the other from the Atlantic coast of the United States.

Key to the species of Bathycrinus.

A. Basal ring squarish, or wider than high.

a. basal ring with straight or concave sides; columnars markedly "dice-box shaped," the articulations prominent; 10–25 short discoidal columnars at summit of stem.

b. arms perfectly smooth, brachials not overlapping.

c. costals and brachials low and rounded, non-carinate.

d. first brachials as long as or longer than wide; columnars short, 25 or more at summit of stem wider than high. (Northern and northeastern Atlantic). . . . . *B. carpenterii* (Danielssen and Koren).

dd. first brachials wider than long; columnars long, 15 or less at summit of stem wider than high. (Northwestern Pacific). . . . . *B. complanatus* A. H. Clark.

cc. costals distinctly carinate; brachials high, compressed, and carinate. (Near the Crozet Islands). *B. australis* A. H. Clark.

bb. brachials with raised and prominent distal edges, imparting a serrate appearance to the arms.

c. costals with a strong, rounded, median keel.

d. lower part of radial funnel much constricted. (Equatorial Atlantic). . . . . . *B. aldrichianus* Wyville Thomson.

dd. radial funnel slopes evenly downward from the upper to the lower edge. (Coasts of southern Europe). . . . . *B. gracilis* Wyville Thomson.

cc. costals with no trace of a median keel. (Off southern Japan). *B. pacificus* A. H. Clark.

aa. basal ring with markedly convex sides; columnars cylindrical; five short discoidal columnars at summit of stem. (Equatorial Pacific). . . . . *B. equatorialis*, sp. nov

AA. Basal ring markedly longer than wide. (Caribbean Sea). *B. caribbeus*, sp. nov.

The following table gives the bathymetrical, thermal, and geographical range of each species of Bathycrinus, and of the genus as a whole, as now known; but the data given will doubtless be greatly modified by future discoveries, as but one species, *B. carpenterii*, can be considered to be even approximately understood; it is probable that the geographical range, even of this species, is much greater than that given, and there may be a corresponding lack of information in regard to the limits of the thermal and bathymetrical altitudes inhabited by it.

	Minimum Depth (Fathoms).	Maximum Depth (Fathoms).	Mean.*	Minimum Temperature (Fahrenheit).	Maximum Temperature (Fahrenheit).	Mean.*	Geographical Distribution.
Bathycrinus	**687**	**2535**	**1581**	**30.9°**	**40.0°**	**36.3°**	Probably cosmopolitan, but bounded by narrow thermal and bathymetrical limits.
B. carpenterii	743	1539	1116	30.9	34.8	32.8	Between Scandinavia and Iceland and northward.
B. gracilis	1093	2435	1764	36.5	36.5	36.5	Eastern Atlantic, from Finisterre south to about the Canary Islands (47° 38′ N. to about 30° N.).
B. aldrichianus	1850	1850	1850	36.6	36.6	36.6	Mid-Atlantic, east of St. Paul's Rocks (1° 47′ N. 24° 26′ W.).
B. caribbeus	687	687	687	40.0	40.0	40.0	Caribbean Sea.
B. australis	1375	1600	1487	34.2	36.6	35.4	Near the Crozet Islands, SW. of the Indian Ocean.
B. complanatus	1567	1567	1567	—	—	—	About 40 miles SSW. ½W. of Copper Island, Commander group.
B. pacificus	905	905	905	36.6°	36.6°	36.6°	Off southern Japan.
B. equatorialis	2320	2320	2320	—	—	—	Between the Marquesas Islands and Central America (0° 3.4′ N. 117° 15.8′ W.).
B. sp.	2535	2535	2535	—	—	—	Off Enderby Land (about 66° S. 50° E.).

* Computed from all the published records.

UNSTALKED CRINOIDS.

Heliometra rhomboidea (P. H. Carpenter.)

This species was met with during the "Albatross" Eastern Pacific Expedition at three stations near the Central American coast; in all, four specimens were secured, a calyx without arms or cirri (Station No. 4622), an immature specimen and fragments of the arms of an adult (Station No. 4621), and a nearly perfect specimen, but with only three cirri remaining (Station No. 4630).

The specimen from Station No. 4630 expands 300 mm. The three remaining cirri have fifty-four, fifty-two, and forty-eight segments respectively. The first pinnule is 18 mm. long, with fifty-five segments, the second 22 mm. long, with fifty-three, and the third 17 mm. long, with thirty-one. The second pinnule is rather stouter than the first, the segments proportionately slightly longer; the third pinnule has the segments considerably elongated; the two following pinnules are about the length of the third, but have twenty-five to thirty segments, of which the terminal five or six are short, the others elongated. In the ten arms syzygia occur in all cases in the third brachials, nine times in the eighth (once in the ninth), once in the twelfth, twice in the thirteenth, five times in the fourteenth, and once in the fifteenth (the tenth arm is missing). Distally syzygia occur forty times at intervals of three brachials, eight times at intervals of four, and six times at intervals of two.

It will be seen that this specimen is almost identical with the one described by Dr. Hartlaub from the bay of Panama. I quite agree with him that it must be referred to *H. rhomboidea,* in spite of the fact that the species is not known between Panama and the Straits of Magellan. It is quite distinct from any of the numerous forms found along the shores of the north Pacific which were unknown at the time Dr. Hartlaub wrote.

The detached arms from Station No. 4621 are somewhat different from those of the specimen just noticed. The brachials are quadrate, all longer than wide, becoming elongate distally and overlapping, the distal border finely serrate; a close comparison shows that the brachials overlap rather more than do those of the other specimen, and the arms are therefore more rough, while the two proximal pinnule segments are proportionately somewhat larger (the first shorter and more oblong) and more expanded laterally, the second being more distinctly trapezoidal. The distal intersyzygial interval is decidedly more variable, being in four cases of two brachials, eight cases of three, thirteen of four, seven of five, six of six, four of seven, one of eight, and one of nine. These differences, however, are of minor systematic importance in this species, and, in fact, in many speices of Heliometra, although in others they may be of considerable value, and I have no hesitation in assigning this specimen, as well as the previous one, to *H. rhomboidea.* Station No. 4621 also yielded a small specimen having an expanse of 150 mm. The cirri have thirty-six segments, the third syzygy is usually in the fourteenth brachial (but once in the fifteenth), and the distal intersyzygial interval is three to five (usually three) segments. It will be seen that this

specimen, in regard to the disposition of the syzygia, most nearly agrees with the first.

The example from Station No. 4622 consisted merely of a calyx, without cirri, and with the arms lost after the third or eighth brachials; as nearly as can be determined, however, it is identical with the preceding.

In the more perfect specimen, the cirri had from forty-eight to fifty-four segments, while *H. rhomboidea* is given as having forty or less. This, however, is a matter of no importance, for the three remaining cirri of the specimen are of the type frequently seen on the extreme upper edge of the centro-dorsal in many species of Heliometra (in the type *H. eschrichtii*, for example) which are somewhat abnormal in being longer than usual, slender, with more than the normal number of segments; these must not be confused with the "long-mature" cirri of Dr. Carpenter, which arise just below them.

The following localities are added to the known distribution of *Heliometra rhomboidea*:

Station No. 4621. 6° 36′ north latitude, 81° 44′ west longitude, 36.4 miles from land; 581 fathoms.

Station No. 4622. 6° 31′ north latitude, 81° 44′ west longitude, 40.8 miles from land; 581 fathoms.

Station No. 4630. 6° 53′ north latitude, 81° 42′ 5″ west longitude, 556 fathoms; green sand, large Globigerinae; bottom temperature, 40.5° F.

Heliometra juvenalis, sp. nov.

Centro-dorsal hemispherical, bearing twenty to thirty cirri; these are 10–12 mm. long with fifteen to twenty segments, mostly somewhat longer than wide, but becoming squarish distally; there are no dorsal spines, but the distal border of the last five to ten segments is somewhat raised; basals plainly visible as interradial tubercles; radials about twice as wide as long; first costals rather shorter than the radials; axillaries pentagonal, about as long as wide; the costals are rounded and well separated laterally; ten arms 75 mm. long, the first brachial short and wedge shaped, the second larger and irregular, the four following oblong; from this point the brachials become obliquely quadrate, longer than wide, becoming more elongate distally; first pinnule 2 mm. long, with four or five squarish segments; second pinnule similar, but slightly longer; third pinnule longer still, with eight segments; the fourth pinnule is 4 mm. long, with about twelve segments; but the fifth is 6 mm. long, with fifteen segments, mostly rather longer than broad, of which the third, fourth, and fifth bear a large rounded genital gland; the fourteen following pinnules are similar, and bear also large genital glands, after which the pinnules become more slender, and do not develop genital glands; syzygia occur in the third, eighth, and twelfth brachials, and distally at intervals of three.

Color (in spirits) dull yellow; probably bright yellow in life.

Types Cat. 283, 284 M. C. Z., from off Cape Raper, Davis Strait; 60 fathoms; taken September 13, 1892, by Rev. A. M. Norman.

The two specimens upon which this species is based are among the most extraordinary unstalked crinoids I have ever seen; that they are adult is shown by the great enlargement of the genital glands, which contain ova; but all the other characters, the prominent basals, long radials, costals, and brachials, and rudimentary lower pinnules, and the few cirrus joints, are clearly juvenile, and in general the specimens appear to be much less developed than some of the very large *H. hondoensis*, which are less than half their size.

Psathyrometra, sp.

Some fragments of arms from "Albatross" Station No. 2818, 0° 29′ 00″ south latitude, 89° 54′ 30″ west longitude (Galapagos Islands), belong to a species of this genus, possibly *P. bigradata*, which has been found in the Galapagos group. The specimen was taken in 392 fathoms on a bottom of black and white sand, the bottom temperature being 43.9° F. The Galapagos specimen of *P. bigradata* was found in 385 fathoms, at a temperature of 43.2° F.

This is the first record for the arms of any species of the genus, outside of the Bering Sea and Sea of Japan, where fairly good specimens have been obtained. Dr. Hartlaub's examples all lacked the arms beyond the syzygy in the third brachial, and this is the condition in which species of this genus are usually recovered, as is the case with the closely allied Zenometra of the Caribbean Sea.

Antedon serrata, sp. nov.

Centro-dorsal low-hemispherical, bearing about thirty cirri; these are 7 mm. or 8 mm. long, and consist of eleven to fourteen segments, the first two short, the others rather longer than wide; the proximal half are more or less "dice-box" shaped; opposing spine minute; radials just visible as small interradial triangles; first costals very short; axillaries triangular, about twice as wide as high; ten arms 45 mm. long; first two brachials wedge shaped, the longer side out; third brachial wedge shaped, the longer side in; next three brachials oblong, then becoming quadrate, at first short, but after the eleventh about as long as wide, and elongate after the middle of the arm; syzygia occur in the third, eighth, and twelfth brachials, and distally at intervals of two; first pinnule 5 mm. long, composed of fifteen segments, the first very short, the second rather longer than broad, then becoming elongated; the ends of the segments are turned outward and produced dorsally, and armed with very fine spines; the five following pinnules are similar to the first, but considerably shorter, with the distal eversion of the pinnule segments more marked, the dorsal projection equal to from one half to nearly the whole length of the segment; the remaining pinnules become more slender, and the projection of the distal end of the pinnule segments gradually dies away.

Color (in spirits) brownish, the arms narrowly banded on about every third brachial with darker.

Type Cat. 254 M. C. Z., from Tokio Bay, Japan, 8–12 fathoms, Alan Owston collection, taken October 22, 1899.

The great amount of eversion and overlapping of the lower pinnule segments make this species one of the most readily distinguishable of the genus.

Antedon psyche, sp. nov.

Centro-dorsal low-hemispherical, bearing thirty to thirty-five cirri, the pole bare; cirri 7 mm. long, with fifteen or sixteen segments, all slightly longer than wide, remarkably uniform, the articulations somewhat expanded; there are no dorsal spines, but the opposing spine is prominent; radials visible as a low triangle in the interradial area; first costals low and wide, deeply incised by the axillary, and with a prominent latero-anterior tubercle; axillaries broader than long, produced posteriorly, where they rise into a slight rounded tubercle; the first costals and axillaries are in apposition laterally, but are not laterally flattened. Ten arms 55 mm. long, the first brachial wedge shaped (the shorter side in), the second irregular, and the third squarish; two following brachials roughly oblong, then quadrate, becoming triangular, longer than wide after the ninth, quadrate again at about the middle of the arm, and much elongate and "dice-box" shaped distally. First pinnule, 4 mm. long, with eight to ten segments, the first squarish, the following becoming progressively elongated; the pinnule tapers gradually from the base to the tip; second pinnule 7 mm. long, at the base about as stout as the first, but flagellate distally; it contains eleven segments, the first shorter than broad, the second longer than broad, the others elongated; the distal segments have the distal edges set with fine spines; the third pinnule resembles the second, but is shorter, and the fourth is shorter still, about the length of the first; the following pinnules become more slender, the distal pinnules being 7 mm. long, very slender, with fifteen to eighteen segments, the first two somewhat enlarged, the first broader than long, the second trapezoidal, and the others greatly elongated and slender.

Syzygia occur in the third, eighth, and twelfth brachials, and distally at intervals of one brachial.

Color (in spirits) light pinkish, the lower part of the arms, the calyx, and cirri, white.

Type Cat. 252 M. C. Z., Japan, probably in the vicinity of Tokio or Sagami bays. Alan Owston collection.

This species belongs to a small but interesting group of the genus Antedon, the species of which are characterized by small size, small number of cirrus segments, and by having the first pinnule never longer, and usually shorter and somewhat stiffer, than those following; the group comprises such species as *Antedon nana*, *A. briseis*, *A. minuta*, and *A. adrestine*, and occurs from Amboina and the Tonga islands northward to Japan. The comparatively large number of cirri on a hemispherical centro-dorsal, and the length of the second pinnule (which is much the longest) suffice to distinguish *A. psyche* from the other described species of this group.

Himerometra acuta, sp. nov.

Centro-dorsal discoidal or low-hemispherical, bearing about thirty-five marginal cirri; these are 20 mm. long with twenty segments, about half of which are rather longer than wide, the remainder squarish; the terminal segments are rather compressed laterally, and have a faint dorsal keel passing into the spine of the penultimate; radials just visible in the angles of the calyx; first costals short, oblong, free laterally, furnished with a rounded lateral projection; axillaries low pentagonal, nearly twice as broad as long; distichals two, articulated; the junctions of the costals, distichals, and lower brachials more or less tubercular, the costals and distichals having rounded lateral projections; twenty arms 85 mm. to 90 mm. long, the first six brachials oblong, the following obliquely quadrate (almost triangular), about half as long as wide, becoming less obliquely quadrate and finally oblong distally; first pinnule 4.5 mm. long, slender, weak, and tapering, with twelve or thirteen segments, the first three short, the remainder becoming progressively longer; second pinnule 10 mm. long, much stouter than the first, stiff and styliform, with fifteen segments, the first two wider than long, the remainder elongated; following pinnules shorter than the first, with about eight segments, gradually increasing in length distally.

Color (in formalin) yellow-brown, the skeleton dull yellow.

Types Cat. 288 M. C. Z. from Fiji, collected November 25, 1897; four specimens.

This species comes nearest to *Himerometra marginata* (P. H. Carpenter) from the Philippines, but the great enlargement of the second pinnule, which is styliform, stiff, and rigid, serves to distinguish it at a glance.

Himerometra heliaster, sp. nov.

Centro-dorsal low-hemispherical or thick discoidal, bearing thirty to thirty-five cirri in two or three more or less irregular marginal rows; cirri 20 mm. to 23 mm. long, with seventeen to twenty-three segments, mostly rather longer than broad, the distal without dorsal spines; opposing spine well developed; terminal claw short and curved; radials concealed; first costals narrow, oblong, about four times as wide as long; costal axillaries pentagonal, somewhat broader than long; costals rounded and widely free laterally, their junction slightly tubercular; distichals and palmars 2, the axillary resembling the costal axillary, the preceding segment like the first costal, but somewhat longer; twenty-five to thirty arms 125 mm. long, the first five or six brachials oblong and slightly tubercular, then becoming quadrate, nearly triangular at the seventh or eighth (much wider than long), then becoming gradually less and less obliquely quadrate, and practically oblong at the tips of the arms; syzygia occur in the third brachials, again between the sixteenth and twentieth, and distally at intervals of one to eleven (usually five or six); first pinnule 9 mm. long, slender and flagellate, with twenty-five segments, the first three squarish, then gradually becoming elongated (about twice as

long as wide, or even a little more, in the outer third of the pinnule), then short again on the terminal segments; second pinnule 15 mm. long, much stouter than the first, stiff, composed of fifteen segments, the first three squarish, then rapidly becoming elongated, reaching a maximum length (on the eleventh or twelfth) of somewhat over three times the width; third and following pinnules much shorter than the first (5 mm.), with twelve to fifteen segments, becoming gradually longer and more slender distally, where they are 9 mm. long. The first distichals, first palmars, and first brachials are united basally, but free distally; the axillaries and second and following brachials are widely free. In one arm of the type both the first and second brachials contain syzygies, and both bear pinnules.

Color (in spirits) grayish brown.

Type Cat. 290 M. C. Z. from Ebon, Marshall Islands, collected by Rev. B. G. Snow.

Himerometra persica sp. nov.

Centro-dorsal low-hemispherical, bearing about twenty-five cirri, a large area at the pole free; cirri 27 mm. long with thirty-five segments, mostly slightly longer than wide, becoming squarish distally, the last sixteen to eighteen bearing sharp dorsal spines; radials just visible; first costals trapezoidal, about three times as broad as long, axillaries pentagonal, about once and a half as broad as long, with a sharp anterior angle; costals rounded and widely free; distichals 4 (3 + 4) or 2; twenty to twenty-five arms 150 mm. long, the first eight brachials roughly oblong, then quadrate (much broader than long), becoming oblong toward the ends of the arms; a syzygy in the third brachial, another at about the seventeenth, and others distally at intervals of five to twelve (usually about seven); distichal pinnule 13 mm. long with thirty-six segments, all somewhat longer than wide, but not much so; the pinnule is very slender and flagellate, the first four segments being the broadest, and being slightly carinate; first brachial pinnule similar, but longer (16 mm.) and stouter basally, the five or six proximal segments sharply carinate, the pinnule then tapering gradually to the long delicate flagellate tip; the next pinnule is the same as that on the second brachial, and of the same length; the next few pinnules decrease rapidly in length, then increase somewhat distally, but do not become very long; the carination of the basal pinnule segments becomes less and less marked, and is not noticeable after the sixth; it is at its maximum on the pinnules of the second and fourth brachials.

Color (in spirits) dull brown, the skeleton somewhat lighter.

Types Cat. 291 M. C. Z. from the Persian Gulf, collected by F. W. Townsend.

This species is not very nearly related to any of the other species of Himerometra; according to the key given by Hartlaub for the "Savignyi Group" it would fall with *H. crassipinna;* but the slender and flagellate lower pinnules serve at once to distinguish it.

Note on six-rayed specimens of Tropiometra carinata (Lam.).

Six-rayed individuals of recent free crinoids have hitherto been regarded as quite rare. Although tetraradiate examples are not uncommon, I can find but a single record of a specimen with more than five radials. It was therefore with considerable surprise that I found among about three hundred and forty specimens of *Tropiometra carinata* no less than seventeen. It is interesting that all of the six-rayed specimens came from Rio Janeiro, all of the sixty or more from Zanzibar and Mauritius being normal. This gives us for the Brazilian specimens 6 % of six-rayed individuals.

These six-rayed specimens are all but one of comparatively small size, the diameter being between 100 mm. and 120 mm., the exception having an expanse of 190 mm.; this last is the only one sexually mature. Normal specimens of this species average from 230 mm. to 270 mm. in diameter, the size of those from Rio, Zanzibar, and the south Pacific being practically the same.

An examination of the disks of twelve of the specimens shows that in three cases it is quite impossible to determine which is the extra ray, as there are six ambulacra converging on the disk, all precisely alike; an examination of the rays themselves also furnishes no clue; one specimen has the interpolated ray between the two on the left side, one has it behind the right posterior, while seven have the extra ray inserted behind the left posterior.

Dr. Carpenter, in his monograph on the "Comatulae" collected by the "Challenger," mentions a small dry six-rayed "Antedon" in the British Museum collection. Suspecting from my examination of these specimens that it was probably an example of the same species, and also from Brazil, I wrote to Professor Bell of the British Museum for information concerning it. He very kindly replied that it was, as I had surmised, *Tropiometra carinata*, but there was no record of the locality whence it had come.

In the recent stalked crinoids it is interesting to note that *Rhizocrinus lofotensis* alone is known with more than five rays, and, as in *Tropiometra carinata*, this variation is confined to a single locality, the coast of Norway.

Among the fossil crinoids six-rayed individuals appear to be extremely rare, the figure by Rosinus (De stellis marinis quondam nunc fossilibus, p. 24, no. 3, pl. 1, fig. 3, 1719) of a six-rayed *Encrinus liliiformis* being the only record I know of this condition.

The genera used for the free crinoids in this paper are those recently proposed in a preliminary paper on a revision of the family Antedonidae (*sensu* A. H. Clark, 1907), in which that family is restricted so as to be equivalent to the genus Antedon, as understood by Dr. P. H. Carpenter. The old genus Antedon is broken up into a number of well-marked homogeneous genera, whereby the interrelations of the various species are much better shown than by the old method of uniting some three hundred or more widely varying specific types under one generic name. The following key shows the relations of these genera to each other from the point of view of differential characters. There are, in addition

to those given, two other types which should be raised to generic rank, but, as they are both West Indian and do not occur in the territory where the free crinoids considered here are found, it has seemed desirable to leave them for a report upon West Indian species.

Key to the genera of Antedonidae.

A. Pinnule ambulacra plated.

a. pinnules stout and prismatic, stiff, and closely set; radials and costals, and lower brachials, strongly flattened laterally (*i. e.* " wall-sided ").

b. first pinnule similar to, but shorter than, those following; cirri very long, with more than 80 segments; the distal pinnules extend for several millimeters beyond the terminal brachials, which are abruptly recurved.

c. centro-dorsal long-conical or columnar, the cirri in 5 double vertical rows; cirri stout; 10–20 arms. . . . .
Asterometra (*Antedon macropoda* A. H. CLARK).

cc. centro-dorsal thick-discoidal or columnar, the cirri without definite arrangement, or in 15 more or less defined vertical rows; cirri slender; 10–30 arms . . . .
Ptilometra (*Comatula macronema* J. MÜLLER).

bb. first pinnule longer than those following; the distal pinnules short, not extending beyond the terminal brachials, which are not incurved.

c. first pinnule markedly larger, stouter, and longer than those following, composed of comparatively few large, stout segments; cirri elongate, slender, always spiny, with more than 25 segments; genital pinnules not differentiated; 10–30 arms . . .
Thalassometra (*Antedon villosa* A. H. CLARK).

cc. first pinnule longer, but smaller and more slender than those following, with much more numerous and shorter joints; cirri short, stout, and smooth, with less than 30 segments; genital pinnules always more or less expanded; 10–50 arms . . . .
Charitometra (*Antedon incisa* P. H. CARPENTER).

aa. pinnules rounded-carinate, the genital pinnules much expanded; costals and lower branchials laterally compressed, with concave sides, the former with broad, thin, flange-like latero-posterior borders; cirri short, stout, and smooth; 10 arms . . . .
Poecilometra (*Antedon acoela* P. H. CARPENTER).

aaa. pinnules cylindrical, stiff and spine-like, well separated, the first small, short, and weak, with squarish joints; proximal segment of lower pinnules (especially the first) enormously expanded; cirri spiny; 10–50 arms . . . . **Calometra** (*Antedon callista* A. H. CLARK).

aaaa. proximal pinnules slender, elongate, cylindrical, stiff, with much elongated segments, the first shorter than the following; distal pinnules strongly prismatic; costals and lower brachials rounded, free laterally; 20–30 arms . . . .
Stylometra (*Antedon spinifera* P. H. CARPENTER).

AA. Pinnule ambulacra not plated.

a. a pinnule on the third (epizygal) brachial.

b. costals united by syzygy; disk always more or less plated . .
Zygometra (*Antedon microdiscus* Bell).

bb. costals united by bifascial articulation; disk naked, or with small, scattered, calcareous granules.

c. lower pinnules stout and prismatic, subequal in length; costals and lower brachials in close apposition, with sharply flattened sides.

d. one of the lower pinnules somewhat enlarged; first two brachials not enlarged; first pinnule as large as or larger than the second or third; distal pinnules do not extend beyond tip of arm; brachials long, triangular, or quadrate; 10 arms . . . .
Nanometra (*Antedon minor* A. H. Clark).

dd. lower pinnules about equal in size, but the first somewhat shorter than those following; distal pinnules extend beyond tip of arm; brachials very short, oblong, or short-quadrate, the first two disproportionately large; 10 arms . . . .
Tropiometra (*Comatula carinata* Lamarck).

cc. one or more of the lower pinnules elongated, slender, and flagellate, cylindrical, or flattened.

d. the greatly elongated and flagellate lower pinnules are composed of very numerous short and broad segments, and are more or less serrate toward the tip; costals always well-separated and rounded; centro-dorsal hemispherical, with very numerous cirri, which are long with numerous segments, long proximally, shorter distally, where they are sharply carinate or bear low spines; terminal claw curved, moderate in length, or short, always with an opposing spine; middle and distal brachials triangular or quadrate; 10 arms . . . . .
Heliometra (*Alecto eschrichtii* J. Müller).

dd. the first of the greatly elongated and flagellate lower pinnules is composed of very numerous short and broad segments; but the others are composed of greatly elongated smooth segments; rays rounded, well-separated; centro-dorsal discoidal, bearing very numerous cirri, which are long, with greatly elongated smooth segments; terminal claw long and nearly straight, with no opposing spine; middle and distal brachials oblong; 10 arms . . . .
Thysanometra (*Antedon tenelloides* A. H. Clark).

ddd. all of the lower pinnules have elongated segments.

e. first segment of the elongated lower pinnules always short; costals and lower brachials usually rounded and free laterally, occasionally

flattened against each other; centro-dorsal hemispherical or discoidal, the cirri without definite arrangement; cirrus segments fairly uniform throughout, one or more always markedly "dice-box shaped;" 10 arms . . . .

Antedon de Fréminville, 1811, (*Asterias bifida* PENNANT).

ee. all the pinnules, especially the lower, greatly elongated, the latter composed of greatly elongated segments of which the first, like those following, is greatly elongated; centro-dorsal conical or columnar, with 5 broad inter-radial areas or ridges dividing it into five radial areas, each with definite vertical rows of cirrus sockets; 10 arms.

f. costals and lower brachials smooth, well separated, and rounded, cirri smooth, with all the segments elongated, arranged in 3, 4, or 5 vertical rows in each radial area.

Psathyrometra (*Antedon fragilis* A. H. CLARK).

ff. costals and lower brachials in close apposition and strongly "wall-sided"; cirri with much elongated segments proximally, very short and spiny segments distally, arranged in two vertical rows in each radial area . . . .

Zenometra (*Antedon columnaris* P. H. CARPENTER).

ccc. lower pinnules cylindrical, one or more very stout, styliform, and more or less elongated.

d. cirri with 50–70 short segments, bearing stout spines distally; first pinnule only enlarged, greatly elongated; following pinnules very short, in abrupt contrast; costals and lower brachials with straight sides, the former rounded and widely separated; brachials triangular or quadrate, rather long; 40–60 arms . . .

Pontiometra (*Antedon andersoni* P. H. CARPENTER).

dd. cirri with 15–40 subequal short segments; the enlarged lower pinnules followed by pinnules of intermediate character.

e. cirri irregularly placed on a discoidal centro-dorsal; costals and lower brachials with convex sides, giving them a characteristic swollen appearance; brachials short, mostly oblong or short-quadrate; 10–50 arms . . . .

Himerometra (*Antedon crassipinna* HARTLAUB).

ee. cirri in ten vertical rows on a conical centro-dorsal; costals and lower brachials with straight sides; brachials long; 10–15 arms.

Adelometra (*Antedon angustiradia* P. H. Carpenter).

aa. no pinnule on the third (epizygal) brachial.

b. centro-dorsal discoidal, the few short and stout cirri in two or three irregular marginal rows; radials and lower brachials not tubercular; 10–30 arms . . . .

Cyllometra (*Antedon manca* P. H. Carpenter).

bb. centro-dorsal conical, the numerous elongate and slender cirri in more or less definite vertical rows; costals and lower brachials strongly tubercular; 10 arms . . . .

Perometra (*Antedon diomedeae* A. H. Clark).

Plate 1.

Fig. 1. *Bathycrinus equatorialis.* Type.
Fig. 2. *Antedon psyche.* Detached arm.
Fig. 3. *Antedon psyche.* Type.
Fig. 4. *Antedon serrata.* Type.
Fig. 5. *Heliometra juvenalis.* Type.

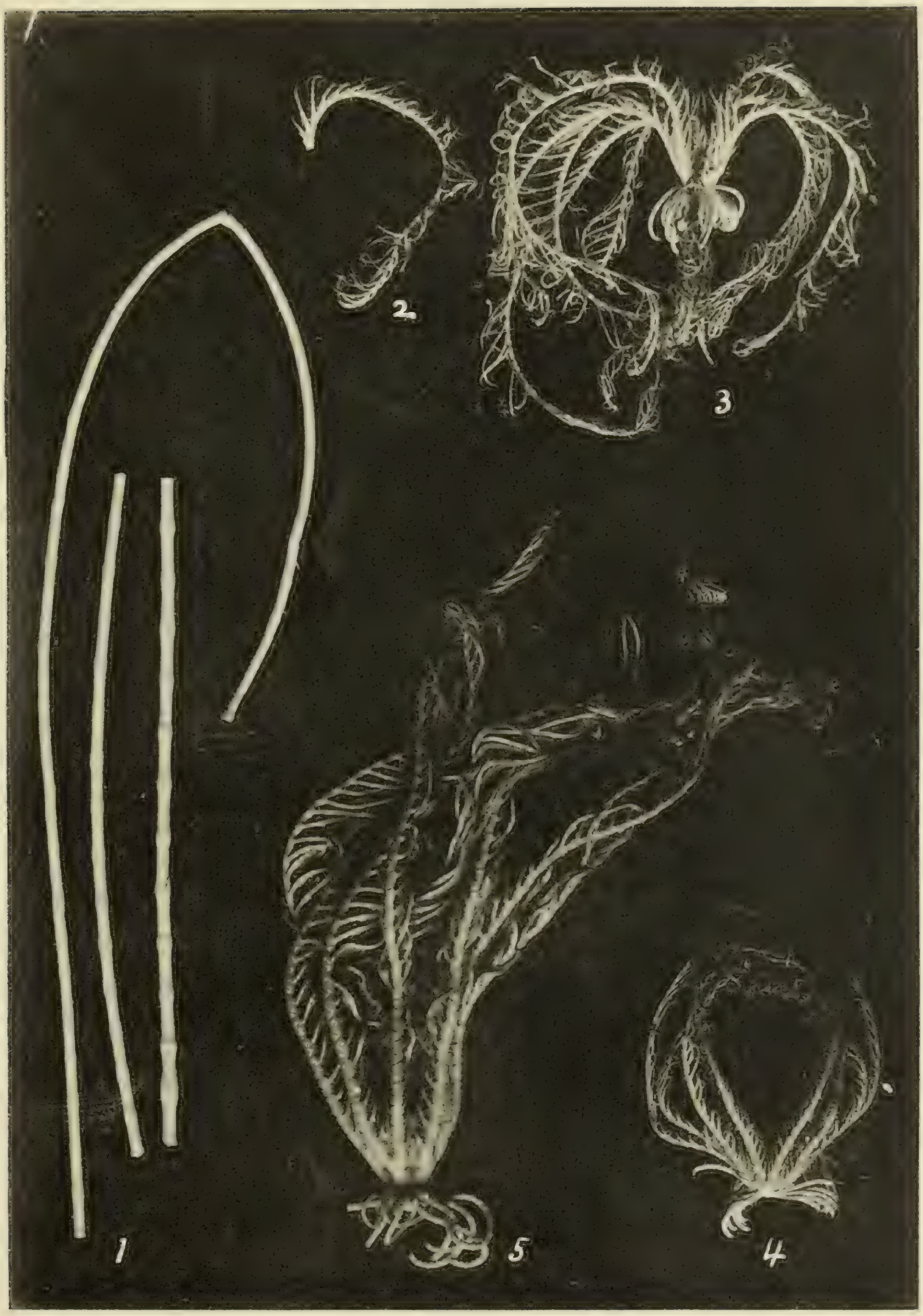
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PLATE 2.

Tropiometra carinata.

Specimens showing six rays.

Fig. 2, specimen with six equal ambulacra. Fig. 4, specimen with five primary ambulacra, that running to the right posterior arm dividing, one half going to a ray interpolated between the right and left posterior rays.

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NEW PLAGIOSTOMIA AND CHISMOPNEA.

BY SAMUEL GARMAN.

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No. 9.—*New Plagiostomia and Chismopnea.* By Samuel Garman.

Plagiostomia.

In the Myliobatidae there are four well-marked genera. Three of these have been established in some manner ever since the time of Cuvier. The fourth, Aetomylaeus, species of which have been recognized quite as long, has been lost in one of the others, hidden by resemblances. Outwardly its species are so like those of Myliobatis that they have readily passed as congeneric. It was only upon the disclosure of internal differences of the structure that the value of certain external peculiarities was given proper consideration. The absence of a serrated spine behind the dorsal fin, if not the result of accident, for one item, has been looked upon as questionably sufficient for specific distinction. On dissection of some of the species, however, this feature is found to be associated with a division of each pectoral at the side of the head, that is, with absence of pectoral rays connecting the cephalic portions with the main sections of the pectoral fins, a characteristic of Aëtobatus and not of Myliobatis in which the species have been located heretofore. We may note slight differences in the appearance of the pectorals opposite the angles of the mouth after discovery of the lack of pectoral rays in these positions, but the import of these features has been overshadowed by the fact that in the species under notice they are associated with a dentition practically the same as that of Myliobatis. Further comparisons assure us that in these species we are dealing with a genus distinct from Myliobatis and considerably more specialized, as is evident from the division of the pectorals and the loss of the serrated dorsal spine. In brief summation, the new genus agrees with Myliobatis in dentition and in nasal valves, while it differs in the divided pectorals and in the lack of a dorsal spine; and it agrees with Aëtobatus in the pectoral divisions, while differing in regard to dentition, nasal valves, and absence of the spine. These peculiarities, with others of less value perhaps, suffice to fix the place of the new genus, Aetomylaeus, as intermediate between Myliobatis and Aëtobatus. How the divergences and the accompanying af-

finities affect the classification may be more clearly seen in the following synopsis:

Pectoral fins continuous at the sides of the head;
  a serrated spine behind the dorsal fin;
    nasal valves confluent, broadly free behind the isthmus;
      teeth of each jaw in a broad median and in narrow lateral series *Myliobatis.*
Pectorals not continuous, the two cephalic parts forming one lobe;
  no serrated spine behind the dorsal fin;
    nasal valves in a quadrangular flap, free behind the isthmus;
      teeth of each jaw in a broad median and in narrow lateral series *Aetomylaeus.*
  A serrated spine behind the dorsal;
    nasal valves in two pointed lobes, not free behind the isthmus;
      teeth of each jaw in a broad single row . . . . *Aëtobatus.*
Pectorals not continuous, cephalic portions in two lobes;
  a serrated spine behind the dorsal fin;
    nasal valves confluent, broadly free behind the isthmus;
      teeth of each jaw in seven or more rows, median more often
        broader . . . . *Rhinoptera.*

Aetomylaeus, gen. nov.

The body and fins of this genus are like those of Myliobatis and of Aëtobatus. It is distinguished from both by absence of a serrated dorsal spine on the tail, from the first by absence of pectoral rays connecting the cephalic with the main lateral portions of the fin, and from the second by the dental laminae, each of which consists of a broad median series at each side of which there are three narrow rows, as in Myliobatis. The mesopterygia are fused with the shoulder girdle, as in Aëtobatus.

This genus partakes of the characters of both the genera mentioned; but by the grouping of those possessed in common, and by the possession of others peculiar to itself, it appears to be entitled to recognition as distinct from either. The type species is that figured by Gray, 1834, in the Illustrations of Indian Zoölogy, **2**, Plate 101, under the name *Myliobatis maculatus*, and described by Müller and Henle in 1841. The species described by Müller and Henle as *Myliobatis milvus* has the same structure, and in all probability *Raia nichofii* of Bloch and Schneider, and *Myliobatis vespertilio* of Bleeker agree with maculatus in their anatomy and should be included. Provisionally the genus may be constituted as below.

No caudal spine; tail long, slender, whip like;
  origin of dorsal fin behind the ends of the bases of the ventrals;
    back armed with small tubercular spines in the middle;
      disk less than twice as wide as long;
        brown-edged ocelli on the hinder part of the disk . . . . . *maculatus.*

Origin of dorsal fin opposite the ends of the bases of the ventrals;
back smooth;
disk less than twice as wide as long;
green brown-edged ocelli on hinder part of disk . . . . *milvus.*
Disk twice as broad as long;
blue cross-bands, about five, disappearing with age, no spots . *nichofii.*
Origin of dorsal fin backward from ends of bases of ventral fins·
back smooth;
disk less than twice as broad as long;
brownish with networks of black lines, anteriorly in bands . *vespertilio.*

Rhinobatus rasus, sp. nov.

The snout of this species is pointed and elongate, more than three and a half times the width of the crown between the orbits. The rostral ridges are close together, parallel in most of their length, and show little or nothing of a groove between them. The crown is broad and has little convexity. The eyes are small and prominent. Each spiracle is as large as the eye and has two folds on the hind margin, the inner one of which is the smaller. In width the nostrils are about one-fourth of the snout. The anterior nasal valve is narrow and does not extend upon the internarial space. Mouth, in width more than one-third of the length of the snout, nearly straight. Entire upper surface covered with fine scales, which are larger near the vertebral column and on the top of the head. A row of larger tubercular scales on each rostral ridge; two stronger tubercles in front of each eye, one or more at the inner edge of each spiracle, a row of nineteen large tubercles from the back of the head to the first dorsal fin, and a pair, the outer one of which is smaller, on each shoulder. Lower surfaces entirely covered by fine shagreen. Of the fins the hinder angle on each dorsal is pointed and the hinder margins are concave; the caudal is narrow.

Brownish, whitish at each side of the rostrum, with a darker area opposite the shoulder girdle on the base of each pectoral fin, and with a clouded spot of darker below the end of the snout on an otherwise uniform whitish lower surface.

Type Cat. 235 M. C. Z., from Akkra, Gulf of Guinea.

This species is distinguished from the species *R. percellens* and *R. rhinobatos* by the pointed snout, the narrow nasal valve, the enlarged scales on the middle of the upper surfaces, and especially by the rostral ridges.

Rhinobatus acutus, sp. nov.

Rhinobatus acutus is readily distinguished from *R. rhinobatos* by its very long and more pointed snout, by its narrow nostrils, and by its wide internarial space, which last is one and one-third times the width of the nostrils; these features also separate this form from any other of the Indo-Asiatic species. Snout long, length little less than one-fourth of the total length, ending in a sharp point. Mouth nearly midway between the pelvis and the end of the snout, slightly arched, in width little less than one-third of the length of the snout. Rostral ridges slender, not widened at the end, confluent at about one-fifth of their length from their

bases, beyond which point to the extremity the ridges are hardly distinguishable. In either a transverse or a longitudinal section between the eyes the crown is convex. Spiracle as large as the eye, with two rudimentary folds on the hind margin of equal size and remote from one another. Nostrils comparatively small, in width about two-thirds of the internarial space and elliptical in shape, rather than short and broad and larger at one end than at the other, as is the case with *R. rhinobatos*, *R. thouini*, and allies; distance of the outer angle of one from that of the other less than half the length of the snout. Anterior nasal valve small, lateral extension from the free portion less than the length of the latter, not extended from the margin of the nostril. The anterior nasal valve is not continued to the inner angle of the nostril; it is not extended upon the internarial space; in fact it is carried very little of the distance from the free flap, or cirrus, toward the angle. Scales very small, keeled or sharp-pointed on the upper surfaces, those on the under surfaces more flattened. Compressed sharp tubercles appear in a row on each rostral ridge, increasing in size backward; three tubercles in front of each orbit, and a couple at the inner edge of each spiracle. About twenty larger tubercles occur between the back of the head and the first dorsal fin in a vertebral row; there is a pair of tubercles at each side of this row on the shoulder girdle, the inner one of each pair being the larger. A single tubercle stands at the origin of the second dorsal fin. Of the dorsal fins the second is somewhat larger than the first; both are convex on the front margin and concave on the hinder. The fin area of the caudal fin is small.

Color an olivaceous-brown or brownish olive on the back, darker toward the spinal column, dingy white at each side of the rostral cartilage and between the ridges at its base, whitish on the lower surfaces.

Type Cat. 807 M. C. Z., from Ceylon.

Raia kincaidii, sp. nov.

On the fins of *Raia kincaidii* the angles are so broadly rounded that the disk is best described as subround. The snout is of medium length; it is outlined in broad curves, and the tip has the appearance of an oblong or quadrangular slightly produced inset; the rostral cartilage is broad at the skull and tapers rapidly about half the way to the tip, where it ends in a sharp point. The eyes are of medium size; they are prominent, and the interorbital space is slightly convex. Mouth moderate, curved forward in the middle, as wide as the distance between the shoulder spines, which is a little less than half that of the mouth cleft from the tip of the snout. Teeth rather large, in thirty-three rows on the upper jaw and thirty-one on the lower, with flattened crowns from which there is a raised sharp cusp at the posterior margin. Gill clefts small, the greatest width not more than half the length of the eye. Tail as long as the disk, depressed and strong anteriorly, tapering gradually to slender, with a dermal fold on each side and with a finlet behind the second dorsal. Dorsal fins equal, separated by a space of the ocular width bearing one or more tubercles. Upper surface covered by small, sharp, closely set hooked scales: a row of twenty-nine larger tubercles —

compressed, hooked, striate-based, buttressed in front — above the vertebrae from the back of the head to the second dorsal fin; no larger tubercles around the eyes or the spiracles. Ventral fins broad, anterior portion of moderate length, notch of medium depth, containing four digits.

Color of the back uniform slaty or leaden-brown, with small spots of black. A white spot on each side of the tail at one-fourth of the distance from the base to the end of the second dorsal fin, and a faint spot of light color near the middle of the hinder half of each pectoral fin. Lower surface of disk white, smooth; lower side of tail darker along the middle.

Type Cat. 1261 M. C. Z., from Friday Harbor, Washington.

The name is given in honor of Dr. Trevor Kincaid, to whom we are indebted for knowledge of the species.

Chismopnea.

Chimaera barbouri, sp. nov.

As compared with other species of the genus the body of this one is moderately stout and the tail is somewhat less elongate. A feature that at once serves to distinguish this species is the shape and height of the second dorsal fin; as on *Chimaera mirabilis* of Collett, this fin is high anteriorly and posteriorly, and the outline is convex, while in the middle of its length there is a deep concavity where the height of the fin is less than half as much, the lowest portion being reached by a gradual descent from either end. The eye is large; it occupies nearly one-third of the length of the head. The snout is massive; its length is greater than that of the eye. The dental plates are thin and sharp on their outer edges. In each vomerine plate there are five enamel rods, as in *C. monstrosa*, but in *C. barbouri*, the inner one of the five, the longest and the strongest, stands at a little distance from the others. Each palatine plate has a pair of prominent longitudinal tritors on its side near the inner edge, and on each mandibular plate there is a single prominence not so elongate as those to which it is opposed on the roof of the mouth. These lateral tritors, being the results of wear on the sides of the enamel rods, only appear in older individuals, and of course are not present in the younger ones, which are provided with the marginal tritors on the edges of the plates, on the ends of the enamel rods, as was pointed out for other species of Chimaera in the article on the Chismopnea, 1904, Bull. M. C. Z., **41**, p. 258. In a measure the palatine and mandibular plates of the specimen before us resemble those of some Callorhynchi, as may be seen by comparing with figures 1–4 of Plate **6** of the mentioned article.

In the first dorsal fin the spine is triangular; it bears hooked spinules on the hinder angles. The dorsals appear to be widely separated, but they are united by a very low fold of membrane. The height of the first dorsal, from origin to apex, is much less than the entire length from the second dorsal to the origin of the first. The greatest length of the rays of the second dorsal approximates the length of the eye, which is about twice the length of the rays in the depth of the concavity of the fin. In height the supracaudal fin is somewhat less than

the second dorsal, and perhaps the rays are a trifle longer than those of the subcaudal, which fin extends much farther forward and backward than the supracaudal. A deep notch not quite reaching the inner edge of the fin separates the second dorsal from the supracaudal, and immediately behind this notch there is a portion of the supracaudal, in the individual under description, which rises in a sharp point followed again by a sharp notch not half the depth of the fin. It may be this point is a mere variation in this specimen. The caudal filament is of medium length; it is apparently complete. There is no separate anal fin. As in *C. affinis,* the pectoral does not reach the ventral; it is broader and less narrowed toward the end than in *C. monstrosa.*

Lateral Line System. — One respect in which this species differs from other Chimaerae is seen in the aural section of the lateral line system. On others the aural makes an angle backward in the middle and from this angle sends back a short line toward the dorsal spine; on the present specimen the line makes a curve across the aural region and has neither the angle nor the line extending backward. It is like that of the Callorhynchus figured in the article on the lateral system, Garman, 1888, Bull. M. C. Z., **17**, Plates **3** and **4**, and is unlike the aural of *Chimaera monstrosa,* as figured on Plate **2** of the same article, or of the other species of the genus. The lateral line on the flank starts from the junction of the occipital and the orbital in a short descending curve, behind which it rises to curve in the opposite direction, making a sigmoid from which it takes a nearly straight course backward to descend to the lower edge of the muscular bands of the tail below the anterior portion of the supracaudal fin. The jugular and the oral portions of the line are separated by a short space at their junction with the orbital. The oral makes a decided curve backward below the orbital above the angular, and another below it; in other Chimaeras the oral is more nearly straight. The outward curve in each cranial is farther forward than on *C. phantasma,* that is, farther from the aural junction, and the oral curves are more pronounced. The great curve, in front of the eye, in the suborbital, is more open than that of *C. phantasma,* more nearly resembling that of *C. mitsukurii;* it does not make so great a turn backward before passing forward to meet the rostral.

The back is dark brown or blackish, shading to light on the lower portions of the flanks, and is marked by white spots: a small spot of white in front of each eye, another behind each orbit, one on each shoulder below the base of the dorsal spine above the lateral line, a larger one below the hinder extremity of the first dorsal, one below the anterior portion of the second dorsal, and another below the lateral line above the base of each ventral fin. Anteriorly the white spots are about the size of the pupil; posteriorly they are larger. Slight cloudings in the brown on the lower parts of the sides may or may not be due to accidents in preservation.

Type Cat. 1281 M. C. Z., from Aomori, near Tsugaru Strait, Japan.

Named in honor of Mr. Thomas Barbour, through whose enthusiastic interest the opportunity of description was provided.

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NEW PHYTOPHAGOUS HYMENOPTERA FROM THE TERTIARY OF FLORISSANT, COLORADO.

By Charles T. Brues.

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March, 1908.

No. 10. — *New Phytophagous Hymenoptera from the Tertiary of Florissant, Colorado.* By Charles T. Brues.

Over a year ago I received from the Museum of Comparative Zoölogy the large collection of undetermined fossil phytophagous and parasitic Hymenoptera collected many years ago by Dr. S. H. Scudder in the Tertiary lake basin at Florissant, Colorado. Since then a large number of additional parasitica have been received from the same locality from Prof. T. D. A. Cockerell, who has been collecting there for the past two summers.

The present paper contains a consideration of the phytophagous forms belonging to the Tenthredinidae, Lydidae, and Siricidae. These are very much less numerous than the parasitic ones.

Three genera and twelve species are described as new, and reference has been made to the more definite records of occurrence of members of the group in the various Tertiary formations of Europe and North America, the only continents where they have been discovered.

A catalogue of the recorded species and genera is also included.

The figures are reproduced from drawings made with the aid of a camera lucida.

TENTHREDINIDAE.

Trichiosomites, gen. nov.

Radial cell of front wings long, not appendiculate; divided at its basal third by a transverse nervure. Submedian cell only a little longer than the median. Anal cell divided into cells connected by a petiole, much as in Pachyprotasis or Hemichroa. Basal vein and first recurrent nervure almost parallel, the second transverse cubitus and the second recurrent nervure interstitial.

The long marginal cell and interstitial second recurrent nervure remind one of Trichiosoma, as does also the oval abdomen. There are such important differences, however, that I feel compelled to erect a new genus for the reception of the single species, which I cannot place in any described genus. The long marginal cell is similar to that of Paremphytus.[1]

[1] Since this paper went to press Mr. S. A. Rohwer of the University of Colorado writes me that he has identified the same species in material from Florissant, which shows that the genus is closely related to Zarea Leach. The antennae are six-jointed.

Trichiosomites obliviosus, sp. nov.

Length 9 mm. Body broad and stout, the width of the abdomen being 3 mm. Color apparently black, with more or less brownish on the abdomen. Wings hyaline, the veins dark. Head rounded on the sides, its surface finely shagreened; mesonotum more coarsely so or finely punctulate. Scutellum smooth. Metanotum more or less rugose. All of the abdominal segments are of nearly equal length, the fifth widest, one and one-half times as wide as the first. Abdomen in outline regularly oval. Marginal cell in front wings very long and narrow, pointed, but not at all appendiculate, divided by a cross-vein at its basal third.

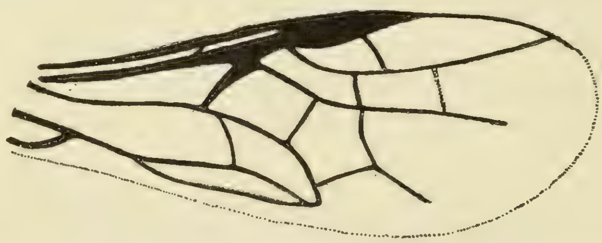

Fig. 1. — *Trichiosomites obliviosus* Brues. Fore-wing.

Humeral area divided by a cross-vein near the origin of the basal vein; submedian cell longer than the median by one-third the length of the transverse median nervure. Basal vein and first recurrent nervure almost parallel. First and second submarginal cells not separated, the second recurrent nervure interstitial with the second transverse cubitus. Anal cell as in Pachyprotasis, divided into two by the fusion of the anterior and posterior nervures; the petiole thus formed as long as the distance from the fusion to the transverse median nervure.

Type. — No. 2036, Mus. Comp. Zoöl., Florissant, Col. (No. 1381, S. H. Scudder Coll.).

Phenacoperga Cockerell.

The type species and only one so far made known is *P. coloradensis* Ckll., from Florissant. It was first described in the genus Perga (Cockerell, : **07**[a]), but later made the type of Phenacoperga by its author (:**08**).

Lophyrus Latreille.

Brischke (**'86**) records the occurrence of Lophyrus in Prussian amber, but the genus has not been found fossil elsewhere.

Hemichroa Stephens.

A single species, *H. eophila* Ckll., has been described from Florissant by Professor Cockerell (: **06**), who refers it to this genus without any doubt. There are no specimens in the collections which I have seen.

Dineura Dahlbom.

Cockerell (:06) has already recognized a species of this genus from Florissant to which he gives the name *Dineura saxorum*, and there is a second one in the present collection. The two may be separated as follows:

Transverse median nervure received much before the middle of the first discoidal cell; second recurrent nervure inserted a considerable distance before the tip of the second submarginal cell . . . . *saxorum* Ckll.

Transverse median nervure received just at or a trifle before the middle of the first discoidal cell; second recurrent nervure inserted at the extreme tip of the second submarginal cell . . . . *laminarum*, sp. nov.

Dineura laminarum, sp. nov.

Probably a female. Length 10 mm. Head and thorax very dark and abdomen pale, except at the tip, where it is brownish. Head rather small and narrow. Antennae black, very gradually attenuated toward the tip, reaching as far back as the base of the metanotum. The mesonotum is brown, with a narrow black border anteriorly, and shades into black behind. Scutellum black. Sides of the metanotum apparently pale like the abdomen. Legs, especially the posterior pair, distinctly preserved, apparently brown; tibiae and tarsi of the hind pair

Fig. 2. — *Dineura laminarum* Brues. Wings.

darker above. Wings hyaline, the veins fuscous or piceous. Humeral cross-vein inserted a short distance before the origin of the basal vein; transverse median nervure inserted just before the middle of the first discoidal cell. Marginal cell long and pointed, its cross-vein distinct. First submarginal cell quadrate, the first transverse cubitus and the first section of the cubitus subequal, second section a trifle longer. Second recurrent nervure inserted at the apex of the second submarginal cell, being almost interstitial with the second transverse cubitus. Anal cell with a long petiole. Recurrent nervure in hind wing inserted three-fifths of the way from the base of the second submarginal cell.

Type. — No. 2037, Mus. Comp. Zoöl., Florissant, Col. (No. 4983, S. H. Scudder Coll.).

This species approaches the genus Mesoneura in the disposition of the recurrent nervures in both pairs of wings, the second being almost interstitial with the second transverse cubitus. This character apparently tends to vary, however, as the vein is more nearly interstitial in one wing than in the other.

It is a broad, stout species.

Pteronus prodigus, sp. nov.

Sex? Length about 7 mm., most of the head broken away. Color dark, varied with paler. The anterior part of the mesonotum and the prothorax are yellowish, while the scutellum and metathorax are darker. The mesonotum has an anterior triangular dark spot and dark lateral margins. Abdomen pale, banded on each segment with fuscous. The bands of the first and second segments reach only half-way across; the following grow wider to the sixth, and the seventh is again narrower. Wings hyaline, the venation as in Pteronus. Humeral field divided by a cross-vein opposite the base of the first discoidal cell. Marginal cell long and lanceolate, not divided. First submarginal cell small, obliquely rounded above, the first and second sections of the cubitus equal. Second sub-

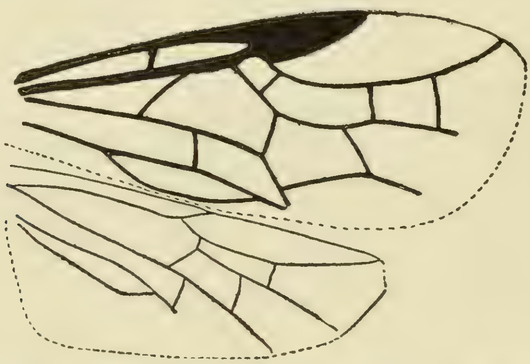

Fig. 3. — *Pteronus prodigus* Brues. Wings.

marginal cell very long, over three times as long as the second section of the cubitus, receiving the two recurrent nervures. Third submarginal cell distinctly longer than high, and higher at the tip than at the base. Anal cell petiolate, its petiole originating just basad to the lower end of the basal nervure. Hind wings with the first discoidal and first submarginal cell separate.

Type. — No. 2038, Mus. Comp. Zoöl., Florissant, Col. (No. 14,071, S. H. Scudder Coll.). It is in a fine state of preservation, showing both front and hind wings, but lacking a part of the head.

The venation in this species is exactly like that of recent species, and the color markings are disposed with a similar tendency to those of *P. ribesii* Scop. and *P. mendicus* Walsh, two common North American species of recent times.

Serres in his Géognosie ('29) has referred a fossil species from Aix to this genus, but it is very doubtfully a member of Pteronus, as the genus is at present restricted.

Scolioneura vexabilis, sp. nov.

Length 9 mm. Broad and stout, dark colored or black with paler markings. Abdomen ferruginous except at the base and apex. Dorsum of thorax indistinctly pale around the edges. Antennae preserved only near the base, black; the joints toward the base about five or six times as long as wide. Thorax as wide as long, and not quite so wide as the oval abdomen, which is twice as long as wide. Wings indistinctly infuscated towards the base, the veins brown. Anal cell lanceolate, petiolate, as wide at its broadest part as three-fourths of the length

FIG. 4. — *Scolioneura vexabilis* Brues. Fore-wing.

of the transverse median nervure. Marginal cell long and narrow, pointed at apex; apparently not divided by a nervure. First submarginal cell small, more or less rounded at its base; second and third long, each receiving a recurrent nervure; basal vein and first recurrent nervure widely divergent behind.

Type. — No. 2039, Mus. Comp. Zoöl., Florissant, Col. (No. 1520, S. H. Scudder Coll.).

This species might perhaps be excluded from Scolioneura, as I cannot make out any cross-vein in the marginal cell. I can find no other suitable place, however, and think that it may best be left here. The hind wings are not well enough preserved to show their venation, but the front ones are in good condition, with the exception of a part of the apical portion.

Selandria Leach.

Brischke ('86) mentions the occurrence of a single specimen belonging to Selandria in Baltic amber. Curtis ('29) compares a form from the lower Oligocene at Aix with *Selandria fuliginosa*, but the latter is evidently the *Tenthredo fuliginosa* now placed in Tomostethus Konow.

Eriocampa Hartig.

Cockerell (:06) has described *Eriocampa wheeleri* from Florissant, and there is a second species to be added from the Scudder collection. The two may be separated as follows:

Second submarginal cell on the radius more than twice as long as the first submarginal on the cubital side; cross-vein in marginal cell strongly oblique; wings infuscated . . . . *scudderi*, sp. nov.

Second submarginal cell on the radial side no longer than the first submarginal on the cubital side. Wings hyaline . . . . *wheeleri* Ckll.

Eriocampa scudderi, sp. nov.

Length about 9 mm. Body seemingly wholly black, with infuscated wings. Nervures piceous. Hind legs, or at least the femora and tibiae, black. Marginal cell long and pointed, the cross-vein strongly oblique, inserted much nearer to the tip than to the base of the second submarginal cell. First submarginal cell small, narrowed at the tip, the first transverse cubitus being only two-thirds the length of the first section of the cubitus. Second submarginal cell long and narrow,

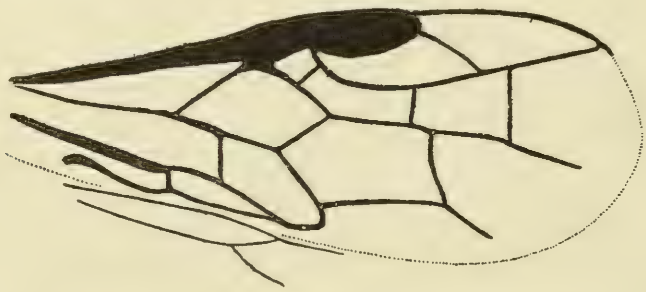

Fig. 5. — *Eriocampa scudderi* Brues. Fore-wing and a small portion of hind-wing.

over three times as long as high at the tip. Basal vein and cubitus arising at the same point, the basal vein longer than the oblique apical side of the first discoidal cell. Anal cell with a moderately oblique cross-vein; rather weakly constricted behind basally, but the nervure is strongly thickened at the constriction.

Type. — No. 2040, Mus. Comp. Zoöl., Florissant, Col. (No. 8298, S. H. Scudder Coll.), very nicely preserved except for the hind wings and the antennae.

Eriocampa, sp.

There is a specimen (No. 2041, Mus. Comp. Zoöl.; No. 9101, S. H. Scudder Coll.), which is not well enough preserved to place positively in this genus, but which probably represents a third species. The wings are brown and the body pale, except the posterior margin of the thorax and the last two or three abdominal segments, which are dark or black. It is quite a strikingly colored species.

Emphytus Klug.

This genus is said to be represented in Baltic Amber by Menge ('56).

Paremphytus, gen. nov.

Similar to Emphytus, but the basal nervure and the first recurrent nervure are widely divergent, not parallel as in that genus. The submedian cell is much longer than the median, and the first transverse cubitus absent. Anal cell divided by an oblique nervure; not constricted behind toward the base. Marginal cell very long and unusually narrow beyond the cross-vein; rounded at the tip but not appendiculate. First and second submarginal cells each receiving

a recurrent nervure. Antennae stout and thick, and possibly with the last joint long, as in Arge and its allies. However, this character is not very plainly to be seen on the specimen.

I have not been able to locate this specimen with any degree of satisfaction. The similarity of the antennae to those of Arge *et al.* is very striking, but it is possible that the last joint is in reality several closely united ones. From these forms it differs at once by the non-appendiculate marginal cell and the divided anal cell. The absence of the first transverse cubitus reminds one of Emphytus, but the position of the first recurrent nervure is entirely different.

Paremphytus ostentus, sp. nov.

Female. Length 9 mm. Elongate, black, with indications of brownish bands on the abdomen. Head very small, considerably narrower than the thorax and about one-half as thick as wide. Abdomen with nearly parallel sides; obtusely rounded at the tip where the terebra projects quite distinctly. Wings distinctly infuscated, especially on the apical half. Marginal cell long, divided, gradually narrowed to the tip, which is rounded but not appendiculate. First submarginal

Fig. 6. — *Paremphytus ostentus* Brues. Fore-wing.

cell very long, as long as the second along the radial nervure; second submarginal strongly widened, so that the second transverse cubitus is twice as long as the first. Submedian cell much longer than the median, the basal nervure and the transverse median vein separated on the median vein by a distance almost as great as the length of the basal nervure. Anal cell with an oblique cross-vein.

Type. — No. 2042, Mus. Comp. Zoöl., Florissant, Col. (No. 11,586, S. H. Scudder Coll.).

Pseudosiobla Ashmead.

Cockerell ('07) has described a single species from Florissant. There are none in the material at hand.

Taxonus Hartig.

Two species of Tertiary saw-flies have been referred to this genus. According to Konow, the well-known authority on the classification of these insects, the species described by Heer ('47) as *Tenthredo vetusta* from the lower Miocene at Radoboj is referable to *Taxonus* ('97).

The second species was described by Scudder in his Tertiary Insects ('90) as

Taxonus nortoni from the Green River beds of Wyoming. From his figures (Pl. **10**, Figs. 26-27) of the wing venation there seems to be no doubt that the generic reference is satisfactory.

Palaeotaxonus, gen. nov.

Body elongate, subparallel; the abdomen long, twice the length of the thorax, all its segments of equal width and of nearly equal length. Wing venation as in Taxonus, but the submedian cell is no longer than the median, the transverse median nervure being interstitial with the basal vein. Anal cell divided by an oblique cross-vein which is nearly as long as the transverse median nervure. Marginal cell long, pointed at the tip, divided by an unusually oblique, curved cross-vein. Second and third submarginal cells each receiving a recurrent nervure near the base.

The present form resembles Taxonus in most respects, but differs very plainly in the interstitial transverse median nervure. This is evidently a primitive trait which is exemplified in several of the other fossil saw-flies here described. On this account I have thought the character to be of generic importance, especially taken in connection with its constancy among large groups of recent Hymenoptera.

Palaeotaxonus typicus, sp. nov.

Length 9.5 mm. Head and thorax black, the abdomen more or less rufous or brownish. Head square behind, rounded toward the front, twice as wide as thick. Antennae of equal thickness for at least the basal two-thirds; black; the joints not very well differentiated in the specimen, but one somewhat beyond the middle is about four times as long as thick. Wings hyaline, humeral area with a cross-vein just basad to the origin of the basal vein, which is close to the origin of the cubitus. Basal vein and first recurrent nervure almost parallel, slightly convergent behind. First section of the cubitus twice as long as the first transverse cubitus, which is one-third the length of the second submarginal cell. Third submarginal cell over three times as wide at apex as at base.

FIG. 7.—*Palaeotaxonus typicus* Brues. Fore-wing.

Described from two specimens.

Type.—No. 2043, Mus. Comp. Zoöl., Florissant, Col. (No. 11,984, S. H. Scudder Coll.). Also, No. 2044, Mus. Comp. Zoöl., Florissant, Col. (No. 7051, S. H. Scudder Coll.).

Dolerus Jurine.

This abundant North American genus has not been found at Florissant, but it is known to occur in the middle Oligocene at Brunstatt in Alsace, where it was noted by Förster ('91). Schöberlin ('88) has also found it in the upper Miocene in Oeningen.

Macrophya pervetusta, sp. nov.

Length 13 mm. Stout, entirely black, or at least very dark. Head nearly as wide as the thorax, over three times as wide as thick antero-posteriorly, the sides strongly convergent in front. Thorax elongate, twice as long as wide, the metathorax being considerably narrower than the mesothorax. Abdomen nearly as long as the head and thorax together, oval, with six segments clearly defined; rounded broadly at the tip, the extreme apex obscured. Wings hyaline, or perhaps slightly infuscated. Venation typical of the genus, much like that of the recent *M. albicincta.* Marginal cell long, its dividing nervure entering the radius

Fig. 8. — *Macrophya pervetusta* Brues. Fore-wing.

much closer to the second transverse cubitus than to the first; first recurrent nervure received just before the middle of the first submarginal cell; the second near the base of the third. Submedian cell but little longer than the median on the externo-medial nervure. Anal cell constricted in the middle until the cross-vein practically disappears; basally it is not appreciably constricted below.

Type. — No. 2045, Mus. Comp. Zoöl., Florissant, Col. (No. 637, S. H. Scudder Coll.).

The venation and the very elongate hind coxae which project backwards laterally so that their tips extend nearly to the middle of the abdomen, determine the systematic position of the species without any doubt. It resembles the present-day *Lagium atroviolaceum* Norton so greatly in size and color that I was tempted to refer it to Lagium. The antennae are not preserved, so that it seems better to refer it to the larger genus Macrophya in absence of positive evidence to the contrary.

Tenthredo Linné.

Four species of Tenthredo, *sensu stricto,* have been discovered at Florissant, one recently described by Cockerell, and three characterized in the present paper.

Brischke ('86) has recognized a species in Baltic amber which he has not described, and Gravenhorst ('35) also noted the occurrence of the genus in the same formation.

Less exact references have been made to Tenthredo by Schöberlin (**'88**), two species from Oeningen; Serres (**'29**) and Heer (**'61**), species from Aix; and Schlotheim (**'29**), one from Baltic amber. These last cannot be regarded as generic determinations, and have no especial significance in the present state of our knowledge.

Florissant species of Tenthredo.

1. Anal cell of hind wings sessile with or touching the first apical cell; discoidal cell of front wings very long, its diagonal length much more than twice the length of the basal nervure . . . . *T. avia*, sp. nov.
   Anal cell of hind wings shorter, not touching the first apical cell, but separated from it by a distinct vein or petiole 2
2. Petiole of anal cell in hind wing over one-half the length of the basal nervure of the front wing, equalling the vein closing the second discoidal cell of hind wing . . . . *T. infossa*, sp. nov.
   Petiole of anal cell very short, less than one-third the length of the basal nervure 3
3. Length 13 mm. First discoidal cell over four times as long as the basal nervure in the front wing . . . . *T. submersa* Ckll.
   Length 17 mm. First discoidal cell less than three times as long as the basal nervure . . . . *T. misera*, sp. nov.

Tenthredo avia, sp. nov.

Female. Length about 13 mm. Body probably variegated with yellow and black. The head is black and the antennae dark. Dorsum of thorax brownish black at the bases of the wings and paler along the parapsidal furrows. Scutellum yellowish; metanotum yellowish, with black reticulations. Median groove of mesonotum very distinct. Abdomen apparently very pale, with a dorsal line of spots, one to each segment; these are small, rounded-quadrate, and diminish in size apically. Wings hyaline, the veins unusually pale in color. Median cell shorter than the submedian by only one-half the length of the transverse median nervure. Third submarginal cell more than twice as high at the apex as at the base. Anal cell not contracted at the insertion of the cross-vein; its sides subparallel, but the posterior side suddenly widens out basally, making the cell more than twice as wide as at the cross-vein. Posterior wing with the anal cell not separated from the first apical cell by a vein.

Type. — No. 2046, Mus. Comp. Zoöl., Florissant, Col. (No. 3763, S. H. Scudder Coll.).

Of the four species from the Florissant shales, this most closely approaches recent representatives of the genus. The preservation of the type is very good, except the sides of the abdomen, which are not distinguishable at first glance. This causes the abdomen to take on a singular subulate appearance quite foreign to its actual form.

Tenthredo infossa, sp. nov.

Length 10.5 mm. Probably a female. Body stout; dark in color. Head black, the thorax more or less light colored anteriorly; the scutellum and metanotum black. Abdomen very dark, narrowly banded with pale on the sutures. Wings hyaline, the veins unusually dark. Antennae black, the apical three joints narrowing; basal joints rather broad, the ones at the beginning of the flagellum three or four times as long as thick. Head small and broad, two and one-half times as wide at the temples as thick antero-posteriorly. Abdomen narrowly oval, twice as long as wide; the extreme apex not preserved, so that the sex cannot be positively determined. Marginal cell moderately long, its cross-vein only slightly curved; first discoidal cell unusually short, hardly more than twice as long diagonally as the length of the basal vein, and more rhombic in

FIG. 9. — *Tenthredo infossa* Brues. Wings.

shape than usual. First submarginal cell quadrate, the first abscissa of the cubitus but little longer than the first transverse cubitus. Submedian cell longer than the median by a little more than the length of the transverse median nervure. Second submarginal cell receiving the recurrent nervure distinctly before the middle. Anal cell slightly constricted at the cross-vein, suddenly widened out behind toward the base to nearly triple its width at the cross-vein. Petiole at apex of anal cell in hind wing as long as the vein closing the second discoidal cell.

Type. — No. 2047, Mus. Comp. Zoöl., Florissant, Col. (No. 11,988, S. H. Scudder Coll.).

One specimen in a fine state of preservation.

This species resembles Macrophya to some extent, more especially on account of the petiolated anal cell of the hind wing, but the form of the anal cell in the front wing is that of Tenthredo. The legs are not at all preserved.

Tenthredo misera, sp. nov.

Female. Length 17 mm. Large and robust; head and thorax dark, probably the head was black and the thorax black, varied more or less with brown. Abdomen pale, very indistinctly indicated in the fossil. Head about two and one-half times as wide as thick. Antennae slender and tapering very gradually to the tip, the joints toward the base of the flagellum three or four times as long as wide. Wings hyaline, the veins rather weak and light in color. Marginal cell long, its cross-vein distinctly arcuate. First submarginal cell considerably narrowed above, the first section of the cubitus being nearly two times as long as the first section of the radius. Second submarginal cell receiving the recurrent nervure at its basal third. Submedian cell longer than the median by somewhat more than the length of the transverse median nervure. First discoidal cell diagonally about two and one-fourth times as long as the basal vein. Anal cell constricted imperceptibly at the cross-vein, and slowly widened basally behind; the cross-vein is distinctly oblique. Petiole at apex of anal cell in hind-wing only one-fourth as long as the vein closing the second discoidal cell.

Type. — No. 2048, Mus. Comp. Zoöl., Florissant, Col. (No. 12,400, S. H. Scudder Coll.).

This is by far the largest species of Tenthredo here described.

LYDIDAE.

Atocus Scudder.

This genus was erected by Scudder ('92) for a single species from Florissant. It comes very close to Neurotoma and Pamphilius as defined by Konow (:05). The only noteworthy character that separates it is the uniformly decreasing length of the antennal joints, the third, or first flagellar, joint being distinctly longer than the second in recent forms. If this character has been overlooked in figuring the type, it can scarcely be considered distinct from Neurotoma, to which it is more closely related than to Pamphilius (= Liolyda) on account of the absence of the humeral cross-vein.

Electrocephalus Konow.

This genus was proposed by Konow ('97) for a single species from Baltic amber. It is related to Janus and Macrocephus.

Cephus Latreille.

An amber species is noted by Menge ('56), but no other fossil forms have been described or mentioned so far as I am aware.

Megaxyela petrefacta, sp. nov.

Female. Length probably about 13 mm., the head nearly effaced. Dark in color, with the sutures of the abdomen pale on the sides; these markings are narrow near the base, but occupy the major parts of the several apical segments. Terebra exserted 1½ mm., curved downward to the blunt tip. The abdomen is somewhat cylindrical and slowly narrowed to near the tip, when it suddenly rounds down to the base of the terebra. The head, antennae, thorax, and legs are not well enough preserved for description, but the wings show clearly their venation, although somewhat overlapped in position. The type is very similar to that of *Megaxyela major* Cresson. The first marginal cell, however, lying just beneath the stigma, is nearly twice as long as wide, and the first recurrent nervure

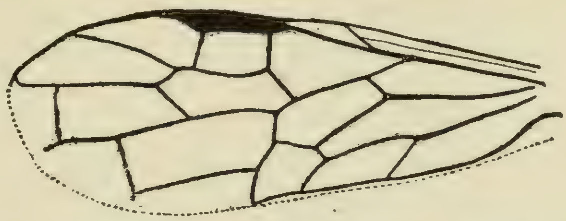

FIG. 10. — *Megaxyela petrefacta* Brues. Fore-wing.

is only two-thirds as long as the vein that meets it to form the tip of the second discoidal cell. Otherwise the venation so far as preserved is scarcely distinguishable from the recent species.

Type. — No. 2049, 2050 (reverse), Mus. Comp. Zoöl., Florissant, Col. (No. 1386, 4295, S. H. Scudder Coll.).

Due to splitting of the rock and subsequent weathering, only the abdomen and wings are preserved, although the entire length can be made out. In venation and size this species is remarkably similar to *M. major* Cresson, from Texas, of which it is undoubtedly a close relative. So far no other recent species have been discovered, and the genus appears to be restricted to the southwestern United States.

SIRICIDAE.

Paururus Konow.

According to Konow (:**05**) the fossil described by Heer as *Urocerites spectabilis* from the lower Miocene of Radoboj belongs to this recent genus, and must be known as *Paururus spectabilis* Heer.

Sirex Linné.

Two species referred to this genus have been recognized in Baltic amber by Klebs ('**89**).

Lithoryssus parvus Brues.

There are three specimens of this species in the present collection (No. 2051–2054, Mus. Comp. Zoöl., Florissant, Col., No. 5080, 5110 (reverse), 5522, and 14,045, S. H. Scudder Coll.), none of them so perfectly preserved as the type, however, which is in the American Museum of Natural History. In one the wings are better preserved, and I find that the humeral area is divided by a cross-vein just before the origin of the basal nervure, and not "apparently undivided," as stated in the original description of the species (:**06**). In size they are all larger than the type, 4–5 mm., but seem otherwise identical.

Cephites Heer.

Two species, *C. oeningensis* and *C. fragilis* Heer, have been placed in this genus by Heer (**'47**), who considers them to be related to Cephus and Xiphydria.[1]

The front wings have two radial cells, the first under but extending beyond the stigma; the first submarginal cell is large, seven-sided, and touches the stigma; second longer and narrower; those beyond, if any, obliterated. Two discoidal cells, the first distinct and moderately large, rhomboidal; the following (third) open apically where the neuration becomes obsolete. Humeral area narrow but distinct. Basal cell wider, the transverse median nervure present.

From this diagnosis it will be seen that Cephites approaches Lithoryssus in many respects, and in view of the fact that such close relationship prevails between many of the Florissant and Oeningen types, it is not unlikely that the two may be quite similar. I have therefore placed the European form near Lithoryssus, tentatively at least.

[1] Konow (**'97**) believes that these are Neuroptera, but Handlirsch (:**07**) does not agree with him, and thinks that they have been correctly placed by Heer. Not having had access to any specimens, and thus compelled to rely on Heer's figures, I have merely pointed out the resemblance which they apparently show to the American Lithoryssus.

CATALOGUE OF TERTIARY PHYTOPHAGA.

Tenthredinidae.

Trichiosomites obliviosus Brues.
Bull. M. C. Z., 1908, **51**, p. 260.
Miocene; Florissant, Colorado.

Cimbex (larva) Menge.
Progr. petrischule Danzig, 1856, p. 24.
Lower Oligocene; Baltic Amber.

Phenacoperga coloradensis Ckll.
Science, 1907, n. s., **26**, p. 446 (*Perga*); *idem*, 1908, **27**, p. 113.
Miocene; Florissant, Colorado.

Lophyrus, sp. Brischke.
Schrift. naturf. gesellsch. Danzig, 1886, n. f., **6**, p. 279.
Lower Oligocene; Baltic Amber.

Hemichroa eophila Ckll.
Bull. Amer. mus. nat. hist., 1906, **22**, p. 501.
Miocene; Florissant, Colorado.

Dineura saxorum Ckll.
Bull. Amer. mus. nat. hist., 1906, **22**, p. 499.
Miocene; Florissant, Colorado.

Dineura laminarum Brues.
Bull. M. C. Z., 1908, **51**, p. 261.
Miocene; Florissant, Colorado.

Pteronus, sp. Serres.
Géogn. terrains tert., 1829, p. 229.
Lower Oligocene; Aix, France.

Pteronus prodigus Brues.
Bull. M. C. Z., 1908, **51**, p. 262.
Miocene; Florissant, Colorado.

Scolioneura vexabilis Brues.
Bull. M. C. Z., 1908, **51**, p. 263.
Miocene; Florissant, Colorado.

Selandria, sp. Brischke.
Schrift. naturf. gesellsch. Danzig, n. f., 1886, **6**, p. 279.
Lower Oligocene; Baltic Amber.

Selandria (*Tenthredo*), sp. Curtis.
Edinburgh new philos. journ., 1829, **7**, p. 295.
Lower Oligocene; Aix, France.

Eriocampa wheeleri Ckll.
Bull. Amer. mus. nat. hist., 1906, **22**, p. 500.
Miocene; Florissant, Colorado.

Eriocampa scudderi Brues.
Bull. M. C. Z., 1908, **51**, p. 264.
Miocene; Florissant, Colorado.

Emphytus, sp. Menge.
Progr. petrischule Danzig, 1856, p. 24.
Lower Oligocene; Baltic Amber.

Paremphytus ostentus Brues.
Bull. M. C. Z., 1908, **51**, p. 265.
Miocene; Florissant, Colorado.

Pseudosiobla megoura Ckll.
Bull. Amer. mus. nat. hist., 1907, **23**, p. 612.
Miocene; Florissant, Colorado.

Taxonus nortoni Scudder.
Tert. ins. N. Amer., 1890, p. 604.
Oligocene; Green River, Wyoming.

Taxonus vetustus Heer.
Insectenf. tertiärg. Oeningen, 1849, **2**, p. 172 (*Tenthredo*).
Konow, Ent. nachr., 1897, **23**, p. 36 (Taxonus).
Upper Miocene; Oeningen.

Palaeotaxonus typicus Brues.
Bull. M. C. Z., 1908, **51**, p. 266.
Miocene; Florissant, Colorado.

Dolerus, sp. Schöberlin.
Soc. entom., 1888, **3**, p. 61.
Upper Miocene; Oeningen.

Dolerus tenax Förster.
Abh. geol. spezialk. Els., 1891, p. 453.
Middle Oligocene; Brunstatt, Alsace.

Macrophya pervetusta Brues.
Bull. M. C. Z., 1908, **51**, p. 267.
Miocene; Florissant, Colorado.

Tenthredo, sp. Serres.[1]
Géogn. terrains tert., 1829, p. 229.
Lower Oligocene; Aix, France.

[1] Compared with *T viridis* L., which is now referred to the genus Rhogogastera Konow.

Tenthredo, sp. Schlotheim.
Petrefactenkunde, 1820, p. 43.
Lower Oligocene; Baltic Amber.

Tenthredo, sp. Gravenhorst.
Uebers. schles. gesellsch. vaterl. cult., 1835, p. 92.
Lower Oligocene; Baltic Amber.

Tenthredo, sp. Brischke.
Schrift. naturf. gesellsch. Danzig., 1886, n. f., **6**, p. 279.
Lower Oligocene; Baltic Amber.

Tenthredo, sp. Schöberlin.
Soc. entom., 1888, **3**, p. 61.
Upper Miocene; Oeningen (two species).

Tenthredo gervaisi Heer.
Saporta, Rech. climat. pays tert., 1861, p. 153.
Lower Oligocene; Aix, France.

Tenthredo submersa Ckll.
Bull. Amer. mus. nat. hist., 1907, **23**, p. 613.

Tenthredo avia Brues.
Bull. M. C. Z., 1908, **51**, p. 268.
Miocene; Florissant, Colorado.

Tenthredo infossa Brues.
Bull. M. C. Z., 1908, **51**, p. 269.
Miocene; Florissant, Colorado.

Tenthredo misera Brues.
Bull. M. C. Z., 1908, **51**, p. 270.
Miocene; Florissant, Colorado.

Lydidae.

Atocus defessus Scudder.
Bull. 93, U. S. G. S., 1892, p. 24, pl. 11, f. 5.
Cockerell, Science, 1907, n. s., **27**, p. 113.
Miocene; Florissant, Colorado.

Pamphilius, sp. (larva) Menge.
Progr. petrischule Danzig, 1856, p. 24.
Lower Oligocene; Baltic Amber.

Electrocephalus strahlendorffi Konow.
Ent. nachr., 1897, **23**, p. 37.
Lower Oligocene; Baltic Amber.

Cephus, sp. Menge.
Progr. petrischule Danzig, 1856, p. 24.
Lower Oligocene; Baltic Amber.

Megaxyela petrefacta Brues.
Bull. M. C. Z., 1908, **51**, p. 271.
Miocene; Florissant, Colorado.

Siricidae.

Paururus spectabilis Heer.
Neue denkschr. schweitz. gesellsch., 1867, **22**, p. 38.
Lower Miocene; Radoboj.

Sirex, 2 spp. Klebs.
Tagbl. naturforschervers., 1889, **62**, p. 269.
Lower Oligocene; Baltic Amber.

Lithoryssus parvus Brues.
Bull. Amer. mus. nat. hist., 1906, **22**, p. 492. fig. 1.
Miocene; Florissant, Colorado.

Cephites fragilis Heer.
Insektenf. tertiärg. Oeningen, 1849, **2**, p. 174.
Upper Miocene; Oeningen.

Cephites oeningensis Heer.
Insektenf. tertiärg. Oeningen, 1849, **2**, p. 173.
Upper Miocene; Oeningen.

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Die fossilen insekten und die phylogenie der renzten formen. Lieferung **6**, Leipzig.

'47. **Heer, Oswald.**
Die insektenfauna der tertiärgebilde von Oeningen und von Radoboj in Croatien., 229 pp., 15 pls.

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Recherches sur le climat et la vegetation du pays tertiaire. Genève et Paris.

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Ueber die fauna des bernsteins. Tag. Deut. nat. vors., **62**, p. 268–271.

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Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

VOL. LI. NO. 11.

SOME JAPANESE AND EAST INDIAN ECHINODERMS.

BY HUBERT LYMAN CLARK.

CAMBRIDGE, MASS., U.S.A.:

PRINTED FOR THE MUSEUM.

APRIL, 1908.

No. 11. — *Some Japanese and East Indian Echinoderms.* By Hubert Lyman Clark.

The Museum of Comparative Zoölogy received in the autumn of 1907 a collection of Echinoderms made by Mr. Thomas Barbour at Amboina and several other islands in the Dutch East Indies, including Dutch New Guinea. There are 362 specimens in this collection, representing thirty-two species, and while none of them is new to science, some are new to the Museum collection and many are of interest because of the localities where they were collected. The value of these specimens is greatly enhanced by Mr. Barbour's notes on their color, habitat, and appearance in life.

From Mr. Alan Owston the Museum has purchased an interesting lot of Echinoderms, consisting of 153 specimens, representing forty species, of which eight are new to science. The following pages give an annotated list of the seventy species contained in these collections and indicated as the Barbour collection and the Owston collection respectively, arranged systematically, with descriptions of the new forms.

CRINOIDEA.

Tropiometra macrodiscus.

Antedon macrodiscus Hara, 1895. Zoöl. Mag., Tokyo, **7**, p. 115.
Tropiometra macrodiscus A. H. Clark, 1907. Smiths. Misc. Coll., **50**, p. 349.

1 specimen, in excellent condition, about 450 mm. in diameter. Color in alcohol uniform deep yellow. Misaki, Sagami Bay, Japan. Owston collection. Kindly identified by Mr. A. H. Clark.

Cyllometra manca.

Antedon manca P. H. Carpenter, 1888. Challenger Reports, **26**, p. 226.
Cyllometra manca A. H. Clark, 1907. Smiths. Misc. Coll., **50**, p. 357.

1 specimen, about 90 mm. in diameter. Color in alcohol pale purple; arms banded with whitish. Uraga Channel, Gulf of Tokyo, Japan; 20–30 fathoms. Owston collection.

ASTEROIDEA.

Archaster typicus.

Müller & Troschel, 1840. Monatsb. Akad. Wiss., Berlin, p. 104.

60 specimens, 60–125 mm. in diameter. Saonek, Waigiou Island, New Guinea. — 45 specimens, 50–120 mm. in diameter. Amboina. Barbour collection.

According to Mr. Barbour's notes, these specimens were taken in very shallow water on a bottom of white sand. The color in life was orange-red, but in drying the specimens nearly all trace of this color was lost, and they became pale yellowish, with only here and there patches of orange-red. One of the specimens from Amboina has 6 rays, while two of those from Saonek have only 4 rays each.

Oreaster nodosus.

Asterias nodosa Linné, 1758. Syst. Nat., ed. 10, p. 661.
Oreaster nodosus Bell, 1884. Proc. Zoöl. Soc. London, p. 70.

18 specimens, Humboldt Bay, New Guinea. — 5 specimens, Sorong, New Guinea. — 3 specimens, Ansus, Jappen Island, New Guinea (135° 44′ E. × 1° 47 S′.). — 1 specimen, Amboina. Barbour collection.

These specimens range from 80 to 300 mm. in diameter and exhibit the greatest diversity in the development of the great tubercles so characteristic of this species. In the youngest specimen there are present 15 tubercles, one at each radial corner of the disc and two on the ridge of each ray; those on the disc are largest and most nearly pointed, while those nearest the tips of the rays are small and nearly spherical. In specimens a trifle older there are 20 or 25 tubercles, one or two more having developed on each ray. The pair of tubercles which are found in large specimens at the proximal end of the rays, one on each side of the ridge, are first seen in an individual 165 mm. in diameter, but are quite small and rounded, and it is only in much larger specimens that they are fully developed. The tubercle at the centre of the disc is present in only six specimens, and none of these is under 200 mm. in diameter. In the largest individual it is wanting, but there are 72 tubercles, arranged as follows: one large one, with two or even three points, at each radial angle of the disc; one rather small but pointed one in each interradius not far from the margin, and in one interradius there are two such tubercles; eight on the ridge of each ray, with a ninth on two of the rays; the usual pair at the base of each ray; and one, two, or even three extra tubercles on the sides of the rays near the base. No less than 20 of the tubercles terminate in two, three, or even four sharp, bare points. — In life, the color of this species shows considerable diversity, ranging from clay-color with the large tubercles muddy brown, or with the large tubercles deep red-brown, becoming vermilion at the base, or with the large tubercles black, with their bases, the tips of the

arms, and the centre of disc claret-red, to a nearly uniform vermilion-red all over. Most of the dried specimens were dirty yellowish, but on being washed with alcohol the vermilion-red color returned to a greater or less degree in different individuals and has not been lost by subsequent drying. The largest specimen (300 mm.) from Amboina is the most uniform and the brightest vermilion. — This species was found chiefly on bottoms where there was more or less vegetation or in open places about coral reefs.

Culcita novae-guineae.

Müller & Troschel, 1842. Sys. Ast., p. 38. *Goniodiscus sebae* Müller & Troschel, 1842. Sys. Ast., p. 58.

3 specimens, 80–130 mm. in diameter. Sorong, New Guinea. — 1 specimen, 75 mm. in diameter. Amboina. Barbour collection.

The small series of Culcitas brought home by Mr. Barbour is of great interest because they prove that the starfish hitherto known as *Goniodiscus sebae* is the young of *Culcita novae-guineae* and not a distinct species closely related to the ancestral stock from which Culcita has sprung, as Döderlein has so ably argued (Semon's Zool. Forsch. Aust., **5**, lf. 4, p. 489–504). The specimen from Amboina is clearly *Goniodiscus sebae,* agreeing not only with Müller and Troschel's description, but with de Loriol's (1885. Mém. Soc. Phys., Genève, **29**, p. 48; Plate 15, figs. 6–6e) description and figures, and with specimens in the Museum of Comparative Zoölogy collection from the Gilbert and Marshall Islands. It cannot, however, be separated in any way from the slightly larger young Culcita from Sorong, which is certainly identical with the other two specimens. On the actinal side the latter are exactly like Döderlein's (1896. Semon's Zool. Forsch. Aust., **5**, lf. 3, p. 301–322) figures (Plate 20, fig. 9) of *C. novae-guineae*, but abactinally one is like *C. n. plana* (Plate 19, fig 1), while the other (the largest of all) is like *C. n. arenosa* (Plate 19, fig. 5). Judging from the 54 Culcitas accessible to me, it seems doubtful whether the varieties (or subspecies) of *C novae-guineae,* so carefully worked out by Döderlein, are really sufficiently distinct to warrant their recognition. — Mr. Barbour's specimens were collected about the reefs and were of a yellowish-brown color, with something of an olive tint when alive. They were all flat and more or less discoidal in life and showed no tendency to the spherical form characteristic of many adult Culcitas.

Gymnasteria carinifera.

Asterias carinifera Lamarck, 1816. Anim. s. Vert., **2**, p. 556.
Gymnasterias carinifera v. Martens, 1866. Arch. f. Naturg., **32** (1), p. 74.

1 specimen, 130 mm. in diameter. Yellowish brown (dried). Sorong, New Guinea. Barbour collection.

Asterina cepheus.

Asteriscus cepheus Müller & Troschel, 1842. Sys. Ast., p. 41.
Asterina cepheus v. Martens; 1866. Arch. f. Naturg., **32** (1), p. 85.

2 specimens, 33 mm. in diameter. Amboina. Barbour collection.

In life these specimens were bluish green above, pale yellowish beneath, and these colors were little changed by drying. But on being washed with alcohol, the blue-green color was changed to orange-red, which faded to reddish-yellow on drying.

Asterina exigua.

Asterias exigua Lamarck, 1816. Anim. s. Vert., **2**, p. 554.
Asterina exigua Perrier, 1876. Arch. Zoöl. Exp., **5**, p. 222.

1 specimen, 30 mm. in diameter. In life dark fawn-color; pale in dried specimen. Under a stone, Tifu Bay, Buru Island, Moluccas. Barbour collection.

Asterina pectinifera.

Asteriscus pectinifer Müller & Troschel, 1842. Sys. Ast., p. 40.
Asterina pectinifera v. Martens, 1865. Arch. f. Naturg., **31** (1), p. 352.

2 specimens, Misaki, Sagami Bay, Japan. — 3 specimens, Tokyo, Japan. Owston collection.

These specimens are 68–90 mm. in diameter, and the color in alcohol is a more or less indistinct orange-red, which becomes paler on drying.

Linckia laevigata.

Asterias laevigata Linné, 1758. Syst. Nat., ed. 10, p. 662.
Linckia laevigata Lütken, 1871. Vid. Med., p. 265.

32 specimens, Amboina. — 6 specimens, Sorong, New Guinea. — 3 specimens, Gani, Halmaheira Island. — 2 specimens, Manokwari, New Guinea. — 1 specimen, Pom, Jappen Island, New Guinea. Barbour collection.

These specimens were all collected on sandy bottoms and were blue, ranging from bright cobalt to brownish blue, with the papular areas more or less distinctly yellow. They were taken directly from the salt water and dried by artificial heat, so that in most cases there has been little change in form or color. They range from 85 to 265 mm. in diameter. Three of those from Amboina have only four rays each. The specimen from Pom has two madreporites but is not otherwise peculiar in any way. Examination of a very large series of specimens (343) in the Museum collection, from twenty stations between the Persian Gulf and Zanzibar on the west, and Samoa and Hawaii on

the cast, has satisfied me that it is futile to attempt to separate *L. multifora* from *laevigata* by any constant characters, although typical examples of the two forms are so easily distinguished. Specimens under 75 mm. in diameter usually show the characters of *multifora*, but in fully grown specimens all intergradations occur between the broad-rayed *laevigata* and the slender-rayed *multifora*. Unfortunately the number of madreporites is worthless as a character, for broad-rayed specimens occasionally have two, while slender-rayed specimens very often have only one. Most specimens from the western part of the Indo-Pacific region seem to have the rays long and slender, while most of those from Australia and the Pacific Islands have the rays short and broad, but this is far from being invariably true. On the whole I think we may retain *multifora* only as a form or variety of *laevigata*. The specimens in the Barbour collection showed a most extraordinary change in color when washed with alcohol. A few were placed in a jar of alcohol, which had been previously used, and their blue tints immediately became vivid orange-red. Thinking the change might be caused by impurities in the alcohol, further experiments were made, which showed that the effect is produced by the alcohol itself, and the mere application of perfectly pure alcohol for a few seconds is sufficient to change a bright blue color to bright orange-red. Subsequent application of an alkali had no visible effect. Continued immersion in alcohol results in the gradual loss of red, the specimens becoming brownish-yellow. On drying, the red specimens seem to retain the color quite well. In the lot of specimens from Amboina there are now to be seen brownish-blue, blue, orange-red, reddish-yellow, and brownish-yellow individuals. These facts emphasize the rule that little importance can be attached to differences in color shown by museum specimens of starfish. — One of the specimens from Amboina and one of those from Manokwari, each bore a specimen of the peculiar gasteropod, *Thyca pellucida*, described by Kükenthal in 1897 as found by him on specimens of Linckia at Ternate (see his "Parasitische Schnecken," Abh. Senck. Nat. Ges., **24** (1), p. 7; Plate 2, figs. 7–9).

Nardoa tuberculata.

Gray, 1840. Ann. Mag. Nat. Hist., **6**, p. 287.

5 specimens, 130–215 mm. in diameter. Sorong, New Guinea. Barbour collection.

These specimens were found on sandy patches among the reefs and in life were a fawn-brown, which in dried specimens has become deep tawny brown, more or less blotched with blackish abactinally on the rays. They agree with de Loriol's (1893) specimens from Amboina in the entire absence of the dusky cross-bands on the rays shown in Herklot's (1868) figure. One of the specimens has only a very few of the characteristic tubercles developed.

Pteraster obesus, sp. nov.

Rays 5. R = 22 mm., r = 16 mm., R = 1.4 r. Breadth of ray at base, 16 mm. Interbrachial arcs shallow. Disc high, vertical diameter, 16 mm.; rays

not clearly marked off. Abactinal surface of rays high, rounded; actinal surface somewhat flat. Distal end of ray upturned, so that ambulacral furrows terminate on abactinal surface. Supradorsal membrane rather thin with no sign of reticulations. Spiracula small but very abundant all over abactinal surface. Paxillae high with numerous spines (8–10 or more) of approximately equal size. About 30 of the paxillae have the spines longer and stouter than the others, and these push the membrane up into more or less conspicuous points or ridges, which are irregularly scattered and give the abactinal surface a rough, almost warty appearance. Apparently there are no other calcareous particles in the membrane. Osculum large, surrounded by about 50 closely webbed long spines, which nearly close it. Ambulacra of moderate width; feet in two rows. Adambulacral plates, each with six (near the mouth there may be seven) spines, the innermost much the smallest, the outermost longest; as the innermost is situated on the inner aboral corner of the plate and the others are on its adoral side, the series is distinctly curved, with the concavity away from the mouth; all the spines are united to each other and to the actino-lateral spine by a membrane which reaches nearly to their free ends, but from which they project distinctly. Actino-lateral spines short, only about half as long again as the outermost adambulacral spine; as they are approximately equal except at tip of ray, the actino-lateral "fringe" is narrow and nearly parallel-sided, and is thus completely concealed from above; aperture-papilla small, free only along its aboral edge. Mouth-plates large, decidedly elevated at their aboral ends, where they terminate in a conspicuous point; the points of the adjacent plates are closely appressed, so there is only one point for the two plates. Each plate bears on its margin 5–7 (usually 6) spines, of which the first is about as long as the plate, flat, about one-fourth as wide as long, and square-cut at the end; the second is about two-thirds as long and, although flat, is somewhat more tapering; the remaining 3–5 spines are very slender, pointed, and about half as long as the first; the spines are all free, no membrane being developed between them. On the surface of each mouth-plate, at about the centre, is a very conspicuous superoral spine; it is longer and much stouter than the first mouth-spine, and terminates in a heavy, sharp, triangular point. — Color of alcoholic specimen, purplish pink, lightest on the ambulacra.

1 specimen from Sagami Bay, Japan; 35° N. × 138° 48′ E., 75 fathoms. Owston collection.

Pteraster multiporus, sp. nov.

Rays 5. R = 16 mm., r = 10 mm., R = 1.6 r. Breadth of ray at base 11 mm. Interbrachial arcs rather deep and angular. Disc moderately high, vertical diameter 8.5 mm.; rays not well marked off. Abactinal surface of rays rather high, rounded; actinal surface flat. Distal end of ray upturned so that ambulacral furrows terminate on abactinal surface. Supradorsal membrane thin, very indistinctly reticulated. Spiracula small but exceedingly numerous all over the abactinal surface. Paxillae low, with numerous spines (8–10 or more), which are

much longer than the stalk that bears them; these spines are slender and approximately equal, so that the entire abactinal surface is relatively smooth. Aside from the tips of these spines there do not appear to be any calcareous particles in supradorsal membrane. Osculum rather small, surrounded by 30–40 rather short, closely webbed spines. Ambulacra rather narrow; feet in two rows. Adambulacral plates each with five (sometimes six) spines, the innermost much the smallest, the outermost longest; as the innermost is situated on the inner aboral corner of the plate and the others are on its adoral side, the series is distinctly curved, with the concavity away from the mouth; all the spines are united to each other and to the actino-lateral spine by a membrane which reaches nearly to their free ends, but from which they project distinctly. Actino-lateral spines short, little longer than outermost adambulacral spine, flattened and widened at the bluntly-rounded tip; they are subequal and the actino-lateral "fringe" is accordingly narrow and nearly parallel-sided. Aperture-papilla small, free only along aboral edge. Mouth-plates moderate, each with six slender, nearly cylindrical but pointed spines along the margin, the innermost largest, outermost smallest; the entire group of twelve spines is completely united by a thin but conspicuous membrane; superoral spines moderately stout, cylindrical but pointed, slightly exceeding the longest oral spines. — Color of alcoholic specimen, purplish pink.

1 specimen from Sagami Bay, Japan; 35° N. × 138° 48′ E., 75 fathoms. Owston collection. Although taken at the same station with *obesus*, it is an entirely distinct species. It is closely allied to *reticulatus* from the Hawaiian Islands, but differs in having webbed oral spines, short, broad, actino-lateral spines, and low paxillae.

List of the species of Pteraster.

militaris O. F. Müller, 1776. Zoöl. Dan. Prod., p. 234. North Atlantic and Arctic Oceans, 10–618 fathoms.

pulvillus M. Sars, 1861. Overs. Norg. Ech., p. 62. North Atlantic and Arctic Oceans, 20–80 fathoms.

danae Verrill, 1869. Proc. Bost. Soc. Nat. Hist., **12**, p. 386. Atlantic Ocean off east coast of South America, 30(?)–55 fathoms.

affinis Smith, 1876. Ann. Mag. Nat. Hist., (4) **17**, p. 108. Royal Sound, Kerguelen Island, 5–28 fathoms.

caribbaeus Perrier, 1883. Stell. du "Blake," p. 216. Subtropical western Atlantic Ocean, 151–422 fathoms.

aporus Ludwig, 1886. Zool. Jahrb., **1**, p. 293. Behring Sea.

rugatus Sladen, 1889. Challenger Report, **30**, p. 473. Antarctic Ocean, vicinity of Heard Island, 150 fathoms.

semireticulatus Sladen, 1889. Challenger Report, **30**, p. 475. Antarctic Ocean, near Marion Island, 69 fathoms.

stellifer Sladen, 1889. Challenger Report, **30**, p. 474. Antarctic Ocean, near Cape Horn, 245 fathoms.

personatus Sladen, 1891. Proc. Roy. Irish Acad., (3) **1**, p. 694. Atlantic Ocean, off Irish coast, 750 fathoms.

ingoufi Perrier, 1891. Ech. Cap Horn, p. K 144. Antarctic Ocean, near Cape Horn, 150 fathoms.

lebruni Perrier, 1891. Ech. Cap Horn, p. K 145. Antarctic Ocean, near Cape Horn and further south, 45–250 fathoms.

alveolatus Perrier, 1894. Tal. et Trav. Ech.: Stell., p. 183. Atlantic Ocean, near Azores, 2256 fathoms.

sordidus Perrier, 1894. Tal. et Trav. Ech.: Stell., p. 182. Atlantic Ocean, off Morocco, 633 fathoms.

multispinus Clark, 1901. Proc. Bost. Soc. Nat. Hist., **29**, p. 326. Puget Sound.

jordani Fisher, 1905. Bull. Bur. Fish., **24**, p. 314. Eastern Pacific Ocean, off San Diego, Cal., 642–650 fathoms.

reticulatus Fisher, 1906. Starfishes Haw. Isl., p. 1098. Pacific Ocean, near Hawaiian Islands, 284–298 fathoms.

obesus Clark, supra.

multiporus Clark, supra.

Key to the species of Pteraster.

Form more or less stellate, R > 1.8 r, usually 2–3.5 r.
- A stout spine (superoral) present on surface of each oral plate.
  - A more or less conspicuous opening (osculum) present in centre of abactinal surface.
    - Adambulacral comb with more than 5 spines.
      - Stalk of paxilla short, not much higher than thick; oral spines 6, similar, none so large as superoral . . . . *militaris.*
      - Stalk of paxilla high and slender; oral spines 5, innermost much the largest, larger than superoral . . . . *caribbaeus.*
    - Adambulacral comb with 3–5 spines.
      - Oral spines 6; supradorsal membrane thick and smooth . . . *lebruni.*
      - Oral spines 4; supradorsal membrane thin.
        - Paxillae with numerous (5–10) spinelets; superoral spine shorter and stouter than innermost oral; 4 well-developed adambulacral spines *affinis.*
        - Paxillae with few (1–3) spinelets, of which one is very long; superoral spine long, equalling innermost oral; innermost of 4 adambulacral spines very small or wanting . . . . *jordani.*
  - No osculum present . . . . *aporus.*
- No superoral spine present.
  - Adambulacral spines 5, in curved series; oral spines 5 . . . . *personatus.*
  - Adambulacral spines 4, in straight series; oral spines 6 . . . . *sordidus.*

Form more or less pentagonal, R < 1.8 r, usually 1.3–1.7 r; superoral spine present.
- Adambulacral armature of 6–7 spines; paxillae spinelets 8–15.
  - Abactinal surface more or less swollen and rough or warty in adult; oral spines 6 (5–7).

Oral spines rather slender, all united by membrane; superoral spine not stout and triangular-pointed; actino-lateral spines much longer near middle of ray than near tip . . . . *pulvillus.*
Oral spines not united by membrane; first two (innermost) very flat and truncate; superoral spine very stout and triangular-pointed; actino-lateral spines of approximately equal length except at very tip of ray . *obesus.*
Abactinal surface not much elevated and not at all warty.
Oral spines 3, united by membrane; $R = 1.5\,r\pm$ . . . . . *multispinus.*
Oral spines 6 or 7, not united by membrane; $R = 1.7\,r\pm$ . . *reticulatus.*
Adambulacral armature of 3–5 (rarely 6) spines.
Oral spines 6.
2 innermost spines long, 4 lateral short, each group united by a web; thus 4 groups to each mouth angle; adambulacral spines usually 4; no spiracula . . . . *alveolatus.*
Oral spines of each mouth angle all (12) united by a common membrane into a single group; adambulacral spines usually 5; spiracula very abundant . . . . *multiporus.*
Oral spines 3–5.
Oral spines not united by a web.
Adambulacral spines short, scarcely projecting beyond web . . *stellifer.*
Adambulacral spines slender, projecting far beyond web . . . *danae.*
Oral spines united together by a web.
Adambulacral spines usually 3, sometimes 4, short, scarcely projecting beyond web . . . . *rugatus.*
Adambulacral spines 3–5, usually 4, projecting far beyond web.
$R = 1.75\,r\pm$; dorsal membrane thin, evidently reticulated *semireticulatus.*
$R = 1.4\,r\pm$; dorsal membrane thick, not at all reticulate . . *ingoufi.*

Echinaster eridanella.

Müller & Troschel, 1842. Sys. Ast., p. 24.

1 specimen, with six rays, 110 mm. in diameter. Very deep crimson-red in life. Manokwari, New Guinea. — 1 specimen, with six rays, 60 mm, in diameter. Red in life. Makassar, South Celebes. Barbour collection.

Asterias rollestoni.

Bell, 1881. Proc. Zoöl. Soc. London, p. 514.

1 young specimen, 50 mm. in diameter. Nearly white, more or less mottled with deep gray abactinally. Tokyo Bay, Japan, five fathoms. Owston collection.

Although this specimen does not correspond perfectly to either Bell's or Döderlein's (Zool. Anz., **25**, p. 333) description, I think there can be little doubt that it belongs to this species.

Asterias similispinis, sp. nov.

Rays 5. $R = 25$ mm., $r = 5$ mm., $R = 5$ r. Interbrachial arcs acute. Rays little flattened, upper surface somewhat convex, sides scarcely vertical, and actinal surface not sharply marked off. Breadth of ray at base 5.5 mm. Disc moderate; vertical diameter 5 mm. Whole abactinal surface quite closely and very irregularly covered with low stout spines, which though blunt are not capitate; there are three or four of these spines to each square millimeter; a median radial line is seldom well marked. Papular areas very variable in size, with from one to five papulae each. Among the spines are scattered small, rather stout and blunt (less commonly, acute) pedicellariae. On sides of ray can be distinguished a dorso-marginal and a ventro-marginal series of spines; space between these distinct but narrow; dorso-marginal series consists of a single (occasionally double near base of ray) longitudinal row of spines similar to and only a little larger than those on abactinal surface; ventro-marginal series made up of two rows which are quite separate at base of ray but become very closely appressed as tip of ray is approached, the lower spine of each pair being placed aboral to the upper; these spines are little longer than those of the dorso-marginal series, are nearly cylindrical, and blunt; near base of ray there may be two spines placed side by side on each infero-marginal plate, in the lower row of the ventro-marginal series. Most of the marginal spines of both series have a group of small pedicellariae at the base, which, however, do not form a surrounding wreath. Adambulacral armature consists of one or two large blunt cylindrical spines, very similar in appearance to the marginals; near base of ray every other plate bears two spines, the outer one nearer the mouth, but at middle of ray and beyond, most of the plates carry only a single spine; all of the adambulacral spines carry small pedicellariae, and there are similar pedicellariae on the plates within the ambulacral groove. There are no spines between the ventro-marginals and the adambulacrals, but no bare space is visible there, as the entire actinal surface is covered by those spines. Oral plates each with two marginal spines at the inner end, the innermost decidedly the larger; a still larger superoral spine is present on the surface of the plate near the middle. Madrepore plate free from spines, small, 1.5 mm. in diameter, situated about half-way between margin and centre of disc. — Color entirely bleached by alcohol.

6 specimens, 23–45 mm. in diameter. Taraku Island, near Nemuro, Hokkaido, Japan. Owston collection.

It is only with the greatest hesitation that I venture to describe a new Asterias, in the face of the large number of imperfectly described or little known species which now make that genus a source of so much difficulty. But as the six specimens before me agree in all essentials and differ in important particulars from any of the species known to me, and most decidedly from any of the species hitherto known from Japan (see Döderlein's key to the Japanese species of Asterias, Zool. Anz., **25**, p. 331), I have felt justified in giving them a new name, based on the remarkable similarity between the adambulacral and marginal spines.

Although the reproductive organs are fairly well developed, I do not feel confident that these specimens are full grown.

OPHIUROIDEA.

Pectinura gorgonia.

Ophiarachna gorgonia Müller & Troschel, 1842. Sys. Ast., p. 105.
Pectinura gorgonia Lütken, 1869. Add. Hist. Oph., pt. 3, p. 33.

4 specimens. Diameter of disc, 10–11 mm. Green above, more or less blotched with yellowish white; arms conspicuously banded with same colors (dry). Sorong, New Guinea. Barbour collection.

Pectinura infernalis.

Ophiarachna infernalis Müller & Troschel, 1842. Sys. Ast., p. 105.
Pectinura infernalis Lütken, 1869. Add. Hist. Oph., pt. 3, p. 33.

34 specimens. Diameter of disc, 7–11 mm. Light gray to yellow-brown above, more or less variegated; arms distinctly banded with light and dark gray (dry). Sorong, New Guinea. Barbour collection.

Ophiolepis annulosa.

Ophiura annulosa de Blainville, 1834. Man. d'Act., p. 244.
Ophiolepis annulosa Müller & Troschel, 1840. Arch. f. Naturg., **6** (1), p. 328.

3 specimens. Diameter of disc, 15–18 mm. Deep purplish brown above, with large spot at centre of disc, one equally large at base of each arm, and from five to eight bands on each arm, dark buff (dry). Sorong, New Guinea. Barbour collection.

Ophiolepis cincta.

Müller & Troschel, 1842. Sys. Ast., p. 90.

2 specimens. Diameter of disc, 10 mm. Dull olive or brownish above; one specimen with arms indistinctly banded with lighter (dry). Amboina. Barbour collection.

Ophioplocus imbricatus.

Ophiolepis imbricata Müller & Troschel, 1842. Sys. Ast., p. 93.
Ophioplocus imbricatus Lyman, 1865. Illust. Catal., p. 69.

1 specimen. Diameter of disc, 14 mm. Dull brownish above on disc; light olive, with nine or ten narrow dark bands on arms. Amboina. Barbour collection.

Ophiozona longispina, sp. nov.

Diameter of disc, 7–10 mm.; length of arm, 15–25 mm. Disc flat, covered by about 60–75 plates, among which the central dorsal plate, the five radial primary plates, and ten radial shields are conspicuous. Radial shields oval, much larger than centro-dorsal, distinctly longer than wide, separated from each other by a longitudinal series of three or four radial plates. (Relative size and arrangement of other dorsal plates decidedly variable.) — Dorsal arm-plates more or less diamond-shape, two outer sides shorter than inner, with angles rounded (especially distal) or proximal truncate; first three or more (even out to the seventh sometimes) distinctly in contact. — Ventral surface of disc with interbrachial spaces covered by 15–25 plates. Oral shields large (about 1 mm. each way), pentagonal, with an inner angle, and outer side curved; lateral sides nearly as long as inner. Adoral plates somewhat variable, approximately quadrilateral but either broad or narrow; distinctly in contact within. Genital plates moderately large and plainly visible. Oral papillae four on each side, variable in relative size. No "infra-dental" papilla. — Ventral arm plates more or less quadrilateral, at least at base of arm, but becoming indistinctly pentagonal, hexagonal, or even heptagonal further out; first three or four wider than long, fourth or fifth about as long as wide, remainder rapidly becoming much longer than wide: first 4–8 distinctly in contact. — Side arm-plates rather small, coming in contact with each other dorsally at from fourth to eighth arm-joint and ventrally at from fifth to ninth joint; each one carries two (rarely three) long, slender, acute, well-spaced spines, which are usually longer than arm-joint and near base of arm, upper spine, which is longer than lower, may equal two arm-joints. — Tentacle-scale single, of moderate size. — Color (in alcohol) nearly white.

3 specimens. Uraga Channel, Gulf of Tokyo, Japan; 70 fathoms. Owston collection.

List of the species of Ophiozona.

pacifica Lütken, 1856. Vid. Med., p. 22. Pacific Ocean, off Mexico and Central America, littoral.

impressa Lütken, 1859. Add. Hist. Oph., pt. 2, p. 101. Atlantic Ocean off Florida, West Indies, and Brazil, 0–300 fathoms.

nivea Lyman, 1875. Illust. Catal., **8**, p. 9. Atlantic Ocean, off Florida and West Indies, 56–424 fathoms.

antillarum Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 127. Atlantic Ocean, off West Indies, 450 fathoms.

depressa Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 128. Pacific Ocean, off Meangis Islands, 500 fathoms.

dubia Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 224. Atlantic Ocean, off West Indies, 539 fathoms.

insularia Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 126. Pacific Ocean, off Fiji Islands. 310 fathoms.

stellata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 125. Pacific Ocean, off New Zealand, 700–1100 fathoms.

tessellata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 223. Atlantic Ocean, off West Indies, 242 fathoms.

clypeata Lyman, 1883. Bull. Mus. Comp. Zoöl., **10**, p. 234. Atlantic Ocean, off West Indies, 151–232 fathoms.

marmorea Lyman, 1883. Bull. Mus. Comp. Zoöl. **10**, p. 233. Atlantic Ocean, off West Indies, 114–250 fathoms.

bispinosa Koehler, 1897. Ann. Sci. Nat., (8) **4**, p. 319. Indian Ocean, off Andaman Islands, 112 fathoms.

alba Lütken & Mortensen, 1899. Mem. Mus. Comp. Zoöl., **23**, p. 102. Pacific Ocean, off Cocos and Galapagos Islands, 770–1360 fathoms.

contigua Lütken & Mortensen, 1899. Mem. Mus. Comp. Zoöl., **23**, p. 101. Pacific Ocean, off Galapagos Islands, 1322–1360 fathoms.

inermis Bell, 1902. Rep. Nat. Hist. "Southern Cross," p. 217. Antarctic Ocean, off Cape Adare, South Victoria Land, 26 fathoms.

casta Koehler, 1904. Oph. Exp. "Siboga," pt. 1, p. 22. Arafura Sea, 312 fathoms.

molesta Koehler, 1904. Oph. Exp. "Siboga," pt. 1, p. 23. Sulu Sea, 705 fathoms; Atlantic Ocean, near Canary Islands, 1175 fathoms.

capensis Bell, 1905. Mar. Inv. South Africa, **3**, p. 256. Indian Ocean, off Cape Colony, 25–900 fathoms.

projecta Koehler, 1905. Oph. Exp. "Siboga," pt. 2, p. 19. Banda Sea, etc., among Dutch East Indies, 8–63 fathoms.

sincera Koehler, 1906. Mém. Soc. Zoöl. France, **19**, p. 12. Atlantic Ocean, off Spain, 679–889 fathoms.

longispina Clark, supra.

Key to the species of Ophiozona.

Tentacle pores not restricted to base of arm; tentacle scales present at least at base of arm.
  Tentacle scales present on all tentacle pores.
    Tentacle scales 2
      Arm-spines 2.
        Arm-spines short, equal; radial shields small, separate or touching *molesta.*
        Arm-spines as long as side arm-plates, upper longer; radial shields large, separate . . . . *bispinosa.*
      Arm-spines 3–5.
        Surface of disc smooth.
          Disk high but flat, margin raised above arms, with a short spine or knob at outer end of each radial shield . . . . *tessellata.*
          Disc-margin raised little, or not at all, above arms; no spine or knob at outer ends of radial shields.
            Oral shields very small, little or not at all larger than one of the swollen adoral plates; arms short, 3–4 times diameter of disc *marmorea.*

Oral shields normal; arms 4–6 times diameter of disc.
Arms about 4 times diameter of disc; lower interbrachial space with less than 30 plates . . . . *nivea.*
Arms about 6 times diameter of disc; lower interbrachial space with more than 50 plates . . . . *clypeata.*
Surface of disc lumpy and irregular, due to numerous, more or less swollen, small plates.
Arms 3 or 4 times diameter of disc; arm-spines nearly or quite equal to joint, rather stout . . . . *impressa.*
Arms 4 or 5 times diameter of disc; arm-spines minute, about half as long as joint . . . . *pacifica.*
Tentacle scale single, though the basal pores may have an extra small scale on the inner side.
Arm-spines 4 . . . . *insularia.*
Arm-spines 2–3.
First side arm-plates of adjacent arms meeting in interbrachial space *dubia.*
First side arm-plates not meeting.
Arm-spines short and peg-like, not exceeding half the arm-joint.
Radial shields well separated.
Most of the disc plates with one or more small but conspicuous tubercles . . . . *projecta.*
Disc plates without tubercles or at most only a single large low tubercle on some of the primary plates.
Upper arm-spine much the shorter; radial shield smaller than central primary plate . . . . *stellata.*
Upper arm-spine the longer; radial shield larger than central primary plate . . . . *depressa.*
Radial shields more or less in contact, or rarely slightly separated.
Arm-spines 3 equal; mouth shield wide, touching first side arm-plate on each side . . . . *casta.*
Arm spines 2, lower longer; mouth shield longer than wide, not in contact with first side arm-plate . . . . *sincera.*
Arm-spines two-thirds as long as arm-joint or longer, radial shields separated.
Side arm-plates meeting above, beyond first upper arm-plate *antillarum.*
Side arm-plates not meeting above, before third upper arm-plate at least.
Side arm-plates entirely separate above, at least on basal half of arm; radial shields small, about as broad as long; upper arm-spine not longer than lower . . . . *contigua.*
Side arm-plates meeting beyond third to eighth upper arm-plate; radial shields large, longer than wide; upper arm-spine the longer.
Basal under arm-plates longer than wide; arm-spine not exceeding joint; mouth shield scarcely pentagonal, lateral sides much shorter than inner . . . . *alba.*

3 or 4 basal under arm-plates wider than long; upper arm-spine exceeding joint; mouth shield pentagonal, lateral sides nearly equal to inner . . . . *longispina.*
Tentacle scales wanting on all except basal pores, where there are 2; arm-spines 3, short and peg-like . . . . *inermis.*
Tentacle pores restricted to 3 basal joints of arm; no tentacle scales present; 3 minute arm-spines . . . . *capensis.*

Ophioglypha sterea, sp. nov.

Diameter of disc 7–8.5 mm.; length of arm 15–20 mm. Disc flat but high (vertical diameter about 2 mm.), covered by rather more than 100 plates, among which the centro-dorsal is conspicuous; relative size and arrangement of dorsal plates variable. Radial shields small, not much larger than centro-dorsal, about as wide as long, broadly in contact; inner ends separated very slightly by a radial plate, outer ends distinctly separated by first upper arm-plate. — Arms high and compressed at base, becoming nearly cylindrical towards tip. First upper arm-plate nearly pentagonal with an angle between radial shields, about half as large as one of them; second plate quadrilateral, about twice as wide as long; these two plates are included in the disc notch; third plate quadrilateral with rounded corners, two or three times as wide as long; next three or four plates more or less hexagonal but wider than long and broadly in contact with each other; succeeding plates longer than wide, gradually becoming diamond-shaped with distal angle rounded; somewhere between fifteenth and twentieth arm-joint, these dorsal plates cease to be in contact with each other. — Upper ends of genital plates conspicuous dorsally on each side of base of arm, rounded, flattened, and as wide as second dorsal arm-plate plus half of first; each plate bears an "arm-comb" of about a dozen spinelets, which are minute, flat, and truncate ventrally, but become longer, cylindrical, and acute dorsally; beneath this comb (and naturally concealed by it) on margin of side arm-plate is a delicate fringe of much more minute spinelets. — Ventral surface of disc with each interbrachial space covered by oral shield and about a dozen small plates. Oral shields very large (about 2 mm. long by 1.5 mm. wide), oval with narrow end inwards. Adoral plates very small, with parallel sides. Oral plates larger than adoral, somewhat swollen at inner end, and so forming a slight projection where they meet. Oral papillae four or five on each side; outermost widest and very flat, next two or three short and blunt, innermost longer and pointed; at apex of jaw is an unpaired, pointed papilla, the longest of all. — First ventral arm-plate nearly triangular with base and outer angle rounded; next three or four plates a trifle larger, more nearly square and broadly in contact; next five or six are longer than wide, more or less octagonal, and still in contact with each other; succeeding plates are hexagonal, pentagonal, and finally nearly circular, and are widely separated from each other. — Side arm-plates large; high, broad, and flat near base of arm where they meet neither above nor below; they meet each other dorsally somewhere after the fifteenth joint and ventrally two or three joints sooner.

Each one carries four minute, well-spaced, pointed spines, about one-third as long as plate, nearly equal or uppermost shortest.— Tentacle pores conspicuous, first six or eight with scales on both sides, but further out tentacle-scales are confined to margin of side arm-plates and resemble so closely the arm-spines that it is not easy to distinguish between them; first pore entirely distinct from mouth-slit, with five scales on outer side and five on inner; second pore has six scales on outer (proximal) side and four on inner; third has six and four respectively; fourth, seven and four; fifth, seven and three; tenth, sixth and none. — Color in alcohol white.

4 specimens, Uraga Channel, near Tokyo, Japan. 70 fathoms. Owston collection.

When Lyman published his key to Ophioglypha (Challenger Report, 1882), he included 58 species as valid. Since then more than 40 additional species have been described, chiefly from the collections of the "Siboga," "Albatross," "Blake," and "Investigator," so that it is with some hesitation that I add another to this already unwieldy group. The genus, however, is not so homogeneous but that it can be separated into subordinate divisions which at some future time it may be desirable to recognize as genera. One of these groups, of which *O. variabilis* Lyman is a good representative, has the following characters: —

Disc and arms high, latter rounded, with very short spines; basal under arm-plates about as broad as long; side arm-plates not meeting below within disc; oral shield large and conspicuous, covering a considerable part (sometimes nearly all) of ventral interbrachial space; adoral plates (usually small) at inner point of oral shield; first pair of tentacle pores not opening into mouth-slit; tentacle scales usually numerous. The following species belong in this group: —

bullata Wyville Thomson. 1873. Nature, **8**, p. 400. South Atlantic Ocean, 1240–2850 fathoms.

convexa Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 84. North Pacific, 2050–2350 fathoms (tropical Atlantic, 114–270 fathoms?).

sculptilis Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 84. Pacific Ocean, off Japan, 1875 fathoms.

variabilis Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 85. Dutch East Indies, 1425 fathoms (West Indies, 175–955 fathoms).

ornata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 86. Tropical Pacific, north of Dutch New Guinea, 2000 fathoms.

lacazei Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 87. South Pacific Ocean, south of Australia; coast of Chili, 2160–2600 fathoms.

lienosa Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 88. Antarctic Ocean, southwest of Australia, 1950 fathoms.

radiata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 89. Pacific Ocean, off west coast of Luzon, Philippine Islands, 1050 fathoms.

undata Lyman, 1878. Bull. Mus. Comp. Zoöl., **5**, p. 90. Pacific Ocean, west of Fiji Islands, 1450 fathoms.

lapidaria Lyman, 1878. Bull. Mus. Comp. Zoöl, **5**, p. 90. Pacific Ocean, off Japan, 565 fathoms.

fasciculata Lyman, 1883. Bull. Mus. Comp. Zoöl., **10**, p. 237. Atlantic Ocean, off Barbados, 288 fathoms.

saurura Verrill, 1894. Proc. U. S. Nat. Mus., **17**, p. 288. Atlantic Ocean, off northeast coast of United States, 471–677 fathoms.

obtecta Lütken & Mortensen, 1899. Mem. Mus. Comp. Zoöl., **23**, p. 119. Pacific Ocean, between Panama and Galapagos; vicinity of Galapagos Islands, 1201–1360 fathoms.

sterea Clark, supra.

Key to variabilis group of Ophioglypha.[1]

Arm-spines 2 or 3 (rarely 4 near base of arm).
  Radial shields in contact for more or less of their length.[2]
    Arm-comb present; basal upper arm-plates not ridged.
      Lower arm-plates separated by side arm-plates, beyond third joint.
        Arm-spines only 2 . . . . *radiata.*
        Arm-spines more than 2.
          Radial shield clearly longer than broad; interradial margin of disc not nearly filled by a single plate . . . . *obtecta.*
          Radial shield about as wide as long; interradial margin of disc filled by a single plate . . . . *ornata.*
      Lower arm-plates in contact at least to sixth joint.
        Primary plates, radial shield, and two large plates in each interradius practically covering disc; oral shield very large, covering nearly entire interbrachial space beneath . . . . *convexa.*
        Disc covered by more than 100 plates; oral shield covering about two-thirds of the interbrachial space . . . . *lacazei.*
    Arm-comb wanting; basal upper arm-plates transversely ridged . . *saurura.*
  Radial shields completely separated by small plates.
    Primary plates large; a single big interradial marginal plate . . . *bullata.*
    Primary plates small; no large interradial plate on margin . . . . *lienosa.*
Arm-spines 4 or more; radial plates more or less in contact.
  Arm-spines 4 or 5.

[1] The species *abdita* Koehler, 1901, and *mundata* Koehler, 1906, very possibly belong in this group, but Koehler does not say whether the first pair of tentacle pores opens into the mouth-slit or not, and I am unable to satisfy myself on this point from the figures. Another species (*insolita* Koehler, 1904) I should certainly have placed here, judging from Koehler's description and figure, but Koehler himself places it in the group in which the first tentacle pores open into the mouth-slit; I cannot reconcile his figure with such a grouping.

[2] The figure of *O. lacazei* given by Lyman in the "Challenger" Report (Plate 6, fig. 5) shows the radial shields widely separated, in direct contradiction to the earlier figure (Bull. Mus. Comp. Zoöl., **5**, Plate 3, fig. 59) and to both of Lyman's descriptions.

Under arm-plates separated beyond third or fourth.
Basal upper arm-plates broadly in contact . . . . *variabilis.*
Basal upper arm-plates separated beyond second . . . . *undata.*
Under arm-plates not separated until at least the sixth.[1]
Disc covered chiefly by 6 primary plates, 10 radial shields, and 5 large interradials; a large interradial plate just outside oral shield ventrally *fasciculata.*
Disc covered by numerous small plates, among which primary plates are not conspicuous; no large interradial plate outside oral shield *sterea.*
Arm-spines 6 (rarely 5?) or more.
Arm-spines not more than 7 . . . . *sculptilis.*
Arm-spines not less than 9 . . . . *lapidaria.*

Ophiocoma brevipes.

Peters, 1852. Arch. f. Naturg., **18** (1), p. 85.

6 specimens. Diameter of disc, 9–17 mm. Color of disk yellowish-brown, with more or fewer dark spots; arms variegated olive and yellowish with narrow dark cross-bands. Amboina. — 3 specimens. Diameter of disc 10–12 mm. Color of disc variegated light and dark brown; arms as in Amboina specimens. Sorong, New Guinea. Barbour collection.

Ophiocoma erinaceus.

Müller & Troschel, 1842. Sys. Ast., p. 98.

1 specimen. Diameter of disc, 8 mm. Color above and below deep purplish-brown, the spines strongly tinged with red. Amboina. Barbour collection.

This specimen is so easily distinguished from the other Ophiocomas in the collection that I am loath to accept the view held by Koehler and others that *erinaceus* is only a variety of *scolopendrina.*

Ophiocoma schoenleinii.

Müller & Troschel, 1842. Sys. Ast., p. 99.

3 specimens. Diameter of disc, 9–15 mm. Color above and below deep purplish-brown, almost black; proximal margin of under arm-plates whitish; as tip of arm is approached, the light color becomes more extensive, especially laterally, passing up on the side arm-plates to the upper surface, until at the extreme tip the arm is prettily banded with white and brown. This peculiar type of coloration is occasionally seen in specimens of *erinaceus*. Amboina. Barbour collection.

[1] Lyman says in his description of *fasciculata*, side arm-plates "meeting neither above nor below," but his figure shows them apparently in contact beyond the sixth under arm-plate.

The re-discovery of this lost species, which Lyman was inclined to regard as identical with *O. wendtii*, while he held both to be of doubtful validity, is a matter of real interest. Koehler (1905, "Siboga" Oph., pt. 2, p. 63; 1907, Bull. Sci. France et Belg., **41**, p. 327) has ably defended the validity of *wendtii*, while the specimens which Mr. Barbour has brought from Amboina show that *schoenleinii* is equally recognizable. It may be distinguished at once from *erinaceus*, which it superficially resembles closely, by the presence of a single large tentacle scale on all the arm-joints beyond the disc; there are usually two on the first arm-joint, sometimes on one side of the second, and very rarely on one side of the third or fourth. The arm-spines are shorter and the oral shields a trifle wider than in specimens of *erinaceus* of the same size. The color also appears to be darker and without any trace of reddish. From *wendtii*, these specimens are easily separated by the short, broad oral shields, nearly as wide at the inner as at the outer end, by the basal under arm-plates which are wider than long, and by the absence of long club-shaped dorsal arm-spines on every third or fourth joint; the color also appears to be a deeper, more blackish brown, and more uniformly dark on the arms. In spite of the fact that it seems to be not only possible but quite easy to divide our Museum specimens of Ophiocoma from the East Indies into these various species, I shall not be surprised if more extended observations, carried on at the shore, prove that *erinaceus*, *schoenleinii*, *scolopendrina*, and *wendtii* are merely intergrading forms of a single variable species.

Ophiocoma scolopendrina.

Ophiura scolopendrina Lamarck, 1816. Anim. s. Vert., **2**, p. 544.
Ophiocoma scolopendrina Agassiz, 1835. Mém. Soc. Sci. Neuchâtel, **1**, p. 192.

47 specimens. Diameter of disc, 6–22 mm. Color dorsally very variable, ranging from uniform deep purplish brown to light yellowish brown, more or less marked with darker and on the arms finely spotted with white; but on the ventral side the under arm-plates and oral shields are always more or less clear yellowish. Sorong, New Guinea. — 3 specimens, similar to above. Amboina. Barbour collection.

Ophiarthrum elegans.

Peters, 1851. Monats. K. Akad. Berlin, p. 464.

1 specimen. Diameter of disc, 12 mm. Color: centre of disc nearly black; margin of disc, arms, and interbrachial spaces yellowish or whitish finely spotted with brown; indistinct cross-bands of brown occur on the arms, especially near tip. Sorong, New Guinea. Barbour collection.

Ophiomastix annulosa.

Ophiura annulosa Lamarck, 1816. Anim. s. Vert., **2**, p. 543.
Ophiomastix annulosa Müller & Troschel, 1842. Sys. Ast., p. 107.

8 specimens. Diameter of disc, 12–26 mm. Color brown, beautifully marked with yellowish white, each upper arm-plate sharply outlined therewith; spines whitish, spotted, or ringed with blackish. Amboina. Barbour collection.

Ophiarachna incrassata.

Ophiura incrassata Lamarck, 1816. Anim. s. Vert., **2**, p. 542.
Ophiarachna incrassata Müller & Troschel, 1842. Sys. Ast., p. 104.

1 specimen. Diameter of disc, 24 mm. Color: disc greenish, centre, and areas over radial shields, light brownish (*not* in marked contrast) spotted with yellow; arms reddish buff; arm-spines light yellow, each with from two to four rings of brownish red; oral shields reddish buff, each with a round yellow spot. Amboina. Barbour collection.

This very handsome specimen, though dry, is nearly perfect. It is of interest because the color agrees fairly well with Müller and Troschel's original description, whereas the "Siboga" specimens seem to have been deep green; at least Koehler says (1905, Oph. "Siboga," pt. 2, p. 65) that Herklot's (1868) colored figure, which is very rich green, variegated on the disc with whitish, is "suffisamment exact."

Ophiothrix longipeda.

Ophiura longipeda Lamark, 1816. Anim. s. Vert., **2**, p. 544.
Ophiothrix longipeda Müller & Troschel, 1842. Sys. Ast., p. 113.

2 specimens. Diameter of disc, 15 mm. Color purple variegated with whitish; spines and spinelets white or nearly colorless. Amboina. — 2 specimens. Diameter of disc 12 mm. Color similar to those from Amboina but lighter. Sorong, New Guinea. Barbour collection.

Ophiocreas papillatus, sp. nov.

Diameter of disc, 15 mm.; length of arm, about 250 mm.; width of arm at base, 4 mm.; height of arm at base, 4 mm. Disc flattened, not higher than arms, concave at centre, covered by a thin skin, which is thickly dotted in radial areas and near margin with minute roundish calcareous granules; of these there are, where thickest, about 75 to a square millimeter. Radial shields long, narrow, and flattened especially towards centre, where they approximately meet; no two are elsewhere in contact. They appear to be made up of several thin, flat, superposed, overlapping plates. Extending from outer end of radial shield at right angles to it, on margin of disc, is a small but very distinct plate, about a millimeter long; it appears to limit upper border of genital slit. Arms approximately cylindrical but flattened ventrally, tapering very gradually, not at all enlarged at base. No upper arm-plates. Skin at base of arm thickly sprinkled with minute calcareous granules like those on disc. Genital plates nearly as large, but not so long, as radial shields; genital slits 4 mm. long, nearly vertical, and parallel. Oral shield wholly invisible. Adoral plates large but indistinctly outlined. Oral plates two, projecting and rather conspicuous. Oral papillae small, rounded, of unequal size, very variable, from five to nine on each side of mouth-slit, situated

far up on sides of slit. Teeth papillae four to six, first or second much larger and more acute than others. Teeth few, apparently only five or six, thick, rounded triangular. — Ventral arm-plates small, separated by rather stout side arm-plates which meet in midline. Tentacle pores very large, diameter equal to or exceeding distance between two consecutive pores; buccal pair without scales but surrounded by a sprinkling of minute granules; first pair on arm much smaller than others and with no tentacle scale; second pair with one tentacle scale; succeeding pores each with a pair of scales. Tentacle scales tapering, rather acute, and more or less spinulose at tip; outer one somewhat shorter than inner, but difference between them is not great on any part of arm; inner one, where longest, is not equal to two arm-joints. Above outer tentacle scale, on each side of every joint until nearly at tip of arm, is a low, rounded tubercle. — Color pale reddish.

1 specimen (dry). Sea of Idzu, Hondo, Japan. Owston collection.

In the large size of the tentacle pores as well as in general appearance, this species is very similar to *O. japonicus* Koehler, but the presence of oral papillae and of granules on the disc, as well as the short nearly parallel genital slits, are such important differences that it does not seem possible that the two can be identical. It must be granted, however, that specific differences in the genus are very slight, and it is by no means certain that the species now recognized are all valid. It seems to be useless to lay any stress on relative proportions of disc and arms, for, as Lyman long ago pointed out, these vary greatly with age. Moreover, the enlargement at the base of the arm, supposed to be characteristic of *oedipus*, appears to be essentially dependent on the condition of the reproductive organs and therefore of very uncertain value. Bearing these facts in mind, I have prepared the following list of, and key to, the species of Ophiocreas. The key shows not only the relationships of the new form herein described, but reveals the remarkably slight differences by which the various species are distinguished from each other.

List of the species of Ophiocreas.

lumbricus Lyman, 1869. Bull. Mus. Comp. Zoöl., **1**, p. 347. Atlantic Ocean, off West Indies, 60–580 fathoms.

abyssicola Lyman, 1879. Bull. Mus. Comp. Zoöl., **6**, p. 64. Pacific Ocean, east of Japan, 2300 fathoms.

oedipus Lyman, 1879. Bull. Mus. Comp. Zoöl., **6**, p. 65. Pacific Ocean, west of Philippine Islands, 500 fathoms; northwest of Halmaheira, 1108 fathoms; and Atlantic Ocean, off Ascension Island, 420–425 fathoms.

carnosus Lyman, 1879. Bull. Mus. Comp. Zoöl., **6**, p. 63. Pacific Ocean, off west coast of Patagonia, 175 fathoms.

caudatus Lyman, 1879. Bull. Mus. Comp. Zoöl., **6**, p. 64. Pacific Ocean, off Enosima, Japan, 345 fathoms.

spinulosus Lyman, 1883. Bull. Mus. Comp. Zoöl., **10**, p. 281. Atlantic Ocean, off West Indies, 116–288 fathoms.

adhaerens Studer, 1884. Abh. K. Pr. Akad. Wiss. Berlin, p. 54. Indian Ocean, off west Australia, 45 fathoms.

constrictus Farquhar, 1900. Trans. N. Z. Inst., **32**, p. 405. Pacific Ocean, off New Zealand.

sibogae Koehler, 1904. Oph. "Siboga," pt. 1, p. 165. Pacific Ocean, off Halmaheira, Kei and Rotti Islands, Dutch East Indies, 113–605 fathoms.

japonicus Koehler, 1907. Bull. Sci. France et Belg., **41**, p. 346. Pacific Ocean, off Japan.

papillatus Clark, supra.

Key to the species of Ophiocreas.

Radial shields and upper arm-plates free from spines.
- Skin of disc and bases of arms free from numerous pits and pores.
  - Oral shields very small, concealed; arms 5; 1 or 2 tentacle scales present on third and commonly on second pair of pores.[1]
    - Tentacle pores small, their diameter much less than distance between 2 consecutive pores.
      - Radial shield long, narrow, thick; genital slits long, exceeding one-eighth of diameter of disc.
        - First 5 or more (rarely only 4) tentacle pores with only 1 scale or none.
          - Skin thick, soft, and smooth; radial shields long, meeting at centre of disc.
            - Skin very thick, wrinkled; no oral papillae or calcareous granules on mouth angles . . . . *carnosus.*
            - Skin thick and minutely tuberculated; small oral papillae or calcareous granules on sides of mouth angles . . . *caudatus.*
          - Skin thin, provided on disc with minute granules; radial shields short, not quite meeting at centre . . . . *oedipus.*
        - First 2 or 3 (rarely 4) tentacle pores with 1 tentacle scale or none.
          - Oral papillae present, 9 or 10 to each mouth angle; skin of disc with numerous minute calcareous granules . . . . *lumbricus.*
          - Oral papillae wanting; skin of disc perfectly smooth . . . *sibogae.*
      - Radial shields short, broad, thin, and flat; genital slits very short, less than one-tenth the diameter of disc[2] . . . . *abyssicola.*
    - Tentacle pores very large, their diameter about equalling distance between 2 consecutive pores.
      - No oral papillae; skin of disc smooth; genital slits long, converging *japonicus.*
      - 5–9 small rounded oral papillae on each side of mouth-slit; skin of disc and bases of arms rough with numerous small calcareous granules; genital slits short and nearly parallel . . . . *papillatus.*

[1] Not counting the buccal pair.

[2] In both the original description (1879) and the Challenger Report (1882) it is said that the genital slits are "5 mm. long," an obvious misprint for 0.5 mm., as shown both by context and figures.

Oral shields large and conspicuous; arms 5–7; no tentacle scales on first 3 pairs of pores, but 2 on each succeeding pore . . . . *adhaerens.*
Skin of disc and bases of arms with numerous minute pits and pores *constrictus.*
Radial shields and upper arm-plates with more or less numerous spines. *spinulosus.*

ECHINOIDEA.

Cidaris metularia.

Cidarites metularia Lamarck, 1816. Anim. s. Vert., **3**, p. 56.
Cidaris metularia Blainville, 1830. Zoöphytes: Dict. Sci. Nat., **60**, p. 212.

1 specimen, 18 mm. in diameter. Guam, Ladrone Islands. Owston collection.

Phyllacanthus baculosa.

Cidarites baculosa Lamarck, 1816. Anim. s. Vert., **3**, p. 55.
Phyllacanthus baculosa A. Agassiz, 1872. Rev. Ech., pt. 1, p. 150.

4 specimens, 24–38 mm. in diameter. Amboina. Barbour collection.

Goniocidaris biserialis.

Stephanocidaris biserialis Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 79.
Goniocidaris biserialis Döderlein, 1887. Jap. Seeigel, p. 10.

3 specimens, 25–32 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan, 20–30 fathoms. — 1 specimen, 25 mm. in diameter. Sagami Bay (34° 58′ N. × 138° 45′ E.), Japan, 77 fathoms. Owston collection.

Goniocidaris mikado.

Discocidaris (*Cidaris*) *mikado* Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 80.
Goniocidaris mikado Döderlein, 1887. Jap. Seeigel, p. 15.

3 specimens, 20 mm. in diameter. Sagami Bay (34° 58′ N. × 138° 45′ E.), 77 fathoms. Owston collection.

Diadema setosum.

Cidaris diadema var. *β setosa* Leske, 1778. Add. Klein, p. xvii (nomen nudum).
Echinometra setosa Leske, 1778. Add. Klein, p. 36; Plate 37, fig. 1, 2.
Diadema setosa Gray, 1825. Ann. Phil., p. 4.

10 specimens, 33–55 mm. in diameter. Amboina. Barbour collection. — 1 specimen, 15 mm. in diameter. Sagami Bay, Japan, 2 fathoms. Owston collection.

The specimens from Amboina are of special interest because they leave no doubt as to what species of Diadema Rumphius (1705) called *Echinometra setosa.* His specimens were the common Diadema of Amboina, and there can be no question that the specimens brought by Mr. Barbour from the same place are the same species. These ten specimens all agree in having the straight, slender pedicellariae, which Mortensen (1904, Dan. Exp. Siam: Ech., p. 11) has pointed out as characteristic of the commonest Indo-Pacific species of Diadema. Dr. Mortensen follows Lovén (1887, Ech. des. by Linn., p. 124) in attaching Linné's name *saxatilis* to this species, but Lovén's argument seems very weak. It is only by altering Linné's description and entirely ignoring his references to figures and to geographical distribution that his *saxatilis* can be applied to any Diadema, and even if all that were done, it would be absolutely impossible to tell to which of the five species recognized by Mortensen, Linné's name should rightly belong. On the other hand, Leske's figures, combined with Rumphius's good description, leave no doubt that a Diadema is the basis of the name *setosa*, and since the type-locality is definitely stated to be Amboina, examination of specimens from that place is bound to show to what particular Diadema the name should be attached. Of course it is quite possible that two or more species may occur at Amboina, but there is no evidence that such is the case, and even if it should prove to be so, the common species is evidently the one which Rumphius describes. It seems, therefore, beyond doubt that *Diadema saxatile* Mortensen, 1904, is the true *Diadema setosum;* whether Lovén's (1887) *saxatile* is the same appears to be indeterminable, while *saxatilis* Linné is almost certainly not a Diadema at all.

The young Diadema from Japan, in the Owston collection, is a very remarkable looking specimen, and I shall not be surprised if it proves to belong to an undescribed species. It differs from all other young Diademas which I have ever seen, or of which I can find records, in coloration. Instead of the usual black (or brown) and white (or whitish) cross-banded primaries, this specimen has the large spines light green with three or four cross-bands of purple. Unfortunately no large tridentate pedicellariae are to be found, although the specimen is perfectly preserved; presumably none have been developed. There are only eight or nine coronal plates in each column, and the number of primary spines in the ambulacra does not exceed ten in each vertical series. Consequently primary spines are not numerous, and secondaries and miliaries are also noticeably few. The longest spines do not exceed 20 mm. — In view of the fact that only a single specimen of this handsome young Echinoid is available, it seems best to record it under the name of the Diadema which is most likely to occur in Sagami Bay, although none is as yet known from there.

Echinothrix calamaris.

Echinus calamaris Pallas, 1774. Spic. Zool., **1**, fasc. 10, p. 31.
Echinothrix calamaris A. Agassiz, 1872. Rev. Ech., pt. 1, p. 119.

2 specimens, 33–57 mm. in diameter. Amboina. Barbour collection.

Asthenosoma owstoni.

Araeosoma owstoni Mortensen, 1904. Ann. Mag. Nat. Hist., (7) **14**, p. 82.
Asthenosoma owstoni A. Agassiz and Clark, 1907. Bull. Mus. Comp. Zoöl., **51**, p. 117.

1 specimen, 160 mm. in diameter. Koajiro, Sagami Bay, Japan. Depth not given. — 1 specimen, 130 mm. in diameter. Yenoshima, Sagami Bay, Japan. Depth not given. Owston collection

Asthenosoma ijimai.

Yoshiwara, 1897. Ann. Zoöl. Jap., **1**, p. 8.

2 specimens, 95–115 mm. in diameter. Sagami Bay, Japan. Depth not given. Owston collection.

Heterocentrotus trigonarius.

Echinus trigonarius Lamarck, 1816. Anim. s. Vert., **3**, p. 51.
Heterocentrotus trigonarius Brandt, 1835. Prod. Anim., p. 66.

6 specimens, 52–76 mm. in long diameter. Djamna, New Guinea. — 1 specimen, 60 mm. in long diameter. Sorong, New Guinea. Barbour collection.

Echinometra mathaei.

Echinus mathaei de Blainville, 1825. Dict. Sci. Nat., **37**, p. 94.
Echinometra mathaei de Blainville, 1830. Dict. Sci. Nat., **60**, p. 206.

14 specimens, 20–37 mm. in long diameter. Amboina. — 6 specimens, 28–38 mm. in long diameter. Sorong, New Guinea. Barbour collection. — 1 specimen, 38 mm. in long diameter. Guam, Ladrone Islands. Owston collection.

Stomopneustes variolaris.

Echinus variolaris Lamarck, 1816. Anim. s. Vert., **3**, p. 47.
Stomopneustes variolaris Agassiz, 1841. Mon. d'Ech.: Obs. Prog. Rec. Hist. Nat. Ech., p. 7.

2 specimens, 45–50 mm. in diameter, remarkable for their deep but distinct green color. Sorong, New Guinea. Barbour collection.

Strongylocentrotus depressus.

Toxocidaris depressa A. Agassiz, 1863. Proc. Acad. Nat. Sci. Phil., p. 356.
Strongylocentrotus depressus A. Agassiz, 1872. Rev. Ech., pt. 1, p. 162.

12 specimens, Yenoshima, Sagami Bay, Japan. — 4 specimens, Yemura, Uraga Gulf, Japan, half a fathom. — 4 specimens, Sagami Bay, Japan. Owston collection.

This series of specimens, ranging in diameter from 14 to 67 mm., shows remarkable diversity in the color of the primary spines, which may be deep purple, purplish red, reddish, or white. All the primaries of any one individual are practically of the same color, consequently the specimens appear at first sight to belong to quite different species. I fail to find any other character, however, associated with this color difference.

Strongylocentrotus pulcherrimus.

Psammechinus pulcherrimus A. Agassiz, 1863. Proc. Acad. Nat. Sci. Phil., p. 357.
Strongylocentrotus pulcherrimus Mortensen, 1903. Ing. Ech., pt. 1, p. 121.

21 specimens, 16–33 mm. in diameter. Sagami Bay (34° 59′ N. × 139° 50′ E.), Japan. — 6 specimens, 25–30 mm. in diameter. Negishi, near Yokohama, Japan. Owston collection.

Strongylocentrotus purpureus.

Toxocidaris purpurea v. Martens, 1866. Arch. f., Naturg., **32** (1), p. 137.

3 specimens, 14–17 mm. in diameter. Yenoshima, Sagami Bay, Japan. — 1 specimen, 47 mm. in diameter. Sagami Bay, Japan. Owston collection.

Temnopleurus hardwickii.

Toreumatica hardwickii Gray, 1855. Proc. Zoöl. Soc. London, p. 39.
Temnopleurus hardwickii A. Agassiz, 1872. Rev. Ech., pt. 1, p. 166.

1 specimen, 42 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan. Owston collection.

Temnopleurus reynaudi.

Agassiz & Desor, 1846. Ann. Sci. Nat., **6**, p. 360.

1 specimen, 17 mm. in diameter. Sagami Bay, Japan, 30–40 fathoms. Owston collection.

Temnopleurus toreumaticus.

Cidaris toreumatica Leske, 1778. Add. Klein, p. 91.
Temnopleurus toreumaticus Agassiz, 1841. Mon. d'Ech., Obs. Prog. Rec. Hist. Nat. Ech., p. 7.

5 specimens, 46–52 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan. — 1 specimen, 33 mm. in diameter. Sagami Bay (34° 59′ N. × 139° 50′ E.), Japan. Owston collection.

These specimens show great diversity in the height of the test, the vertical diameter varying from less than .50 to more than .65 of the horizontal diameter.

Salmacis sphaeroides.

Echinus sphaeroides Linné, 1758. Sys. Nat., ed. 10, p. 664.
Salmacis sphaeroides Lovén, 1887. Ech. Linn., p. 69.

2 specimens, 55 and 63 mm. in diameter. Amboina. Barbour collection.

Mespilia globulus.

Echinus globulus Linné, 1758. Sys. Nat., ed. 10, p. 664.
Mespilia globulus Agassiz & Desor, 1846. Ann. Sci. Nat., **6**, p. 358.

5 specimens, about 20 mm. in diameter. Yenoshima, Sagami Bay, Japan. — 1 specimen, 27 mm. in diameter. Aburatsubo, Sagami Bay, Japan. Owston collection.

In the specimen from Aburatsubo the spines are very bright red, in striking contrast to the dark green, bare interambulacral spaces, but in the specimens from Yenoshima the colors are more yellowish and not nearly so bright.

Salmacopsis olivacea.

Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 93.

3 specimens, about 18 mm. in diameter. Sagami Bay (33° 9′ N. × 138° 42′ E.), Japan, 30–40 fathoms. — 2 specimens, about 20 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan, 40 fathoms. — 1 specimen, 24 mm. in diameter. Uraga Channel, Gulf of Tokyo, Japan, 20–30 fathoms. — 1 specimen, 14 mm. in diameter. Aburatsubo, Sagami Bay, Japan. Owston collection.

The specimen from Aburatsubo is remarkable for the very bright green color of the interambulacra, contrasting sharply with the white ambulacra. The others are all olive-brown with more or less evident traces of greenish but with little contrast between interambulacra and ambulacra; the genital and ocular plates are blackish.

Prionechinus agassizii.

Wood-Mason & Alcock, 1891. Ann. Mag. Nat. Hist., (6) **8**, p. 441.

2 specimens, 4.5 and 9 mm. in diameter. Nearly white but with a pink tinge. Sagami Bay (35° 32′ 14″ N. × 139° 31′ E.), Japan, 400 fathoms. Owston collection.

Toxopneustes pileolus.

Echinus pileolus Lamarck, 1816. Anim. s. Vert., **3**, p. 45.
Toxopneustes pileolus Agassiz, 1841. Mon. d'Ech., Obs. Prog. Rec. Hist. Nat. Ech., p. 7.

4 specimens, 62–114 mm. in diameter. Sagami Bay (35° 2′ N. × 138° 52′ E.), Japan. Owston collection.

Clypeaster japonicus.

Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 100.

2 specimens, 87 and 100 mm. in long diameter. Sagami Bay, Japan. — 1 specimen, 54 mm. in long diameter. Sagami Bay (35° 2′ × N. 138° 50′ E.), Japan, 55 fathoms. — 2 specimens, 15 mm. in long diameter. Misaki, Sagami Bay, Japan. Owston collection.

The young ones from Misaki are too small to show specific characters plainly, but the ventral surface is so concave that I think there is little doubt that they are *japonicus*. The specimen 54 mm. long is very different from the larger adults, but its peculiarities may be due to immaturity. The primary spines are relatively few dorsally, only about one-third to one-half as many per square centimeter as in typical *japonicus* (20–25 as against 50–75), and instead of being greenish-white with a broad reddish or brownish band around the middle, they are glassy white; some, however, do show a faint brown band.

Clypeaster scutiformis.

Echinus scutiformis Gmelin, 1788. Linn. Sys. Nat., p. 3184.
Clypeaster scutiformis Lamarck, 1816. Anim. s. Vert., **3**, p. 14.

1 specimen, a broken, bare test, 23.5 mm. in long diameter. Buleleng, Bali, Dutch East Indies. Barbour collection.

Laganum laganum.

Echinodiscus laganum Leske, 1778. Add. Klein, p. 140.
Lagana laganum de Blainville, 1830. Dict. Sci. Nat., **60**, p. 196.

4 specimens, including 3 bare tests, 24–32 mm. long. Saonek, Waigiou, New Guinea. Barbour collection.

According to our now generally accepted codes, the name *bonani* cannot be retained for this species, as it is one of Klein's (1734) names re-introduced by Agassiz in 1841.

Laganum pellucidum.

Peronella (*Laganum*) *pellucida* Döderlein, 1885. Arch. f. Naturg., **51** (1), p. 104.
Laganum pellucidum A. Agassiz & Clark, 1907. Bull. Mus. Comp. Zoöl., **51**, p. 128.

2 specimens, about 22 mm. long. Misaki, Sagami Bay, Japan. Owston collection.

Arachnoides placenta.

Echinus placenta Linné, 1758. Sys. Nat., ed. 10, p. 666.
Arachnoides placenta Agassiz, 1841. Mon. d'Ech. Scut., p. 94.

1 specimen, a broken, bare test. Ampenan, Lombok Island, Dutch East Indies. Barbour collection.

Astriclypeus manni.

Verrill, 1867. Trans. Conn. Acad., **1**, p. 311.

3 specimens, 100–125 mm. in diameter. Sagami Bay, Japan. Owston collection.

Spatangus pallidus sp. nov.

Test broad and flattened; width (47 mm.) nearly equal to length (49 mm.), but height little more than half as much; greatest width just back of abactinal system; greatest height (30 mm.) a trifle further back; at labrum, height only 26 mm. Cordate form of test not conspicuous as anterior ambulacral furrow is shallow, only about 2 mm. deep at ambitus. Anterior petals a trifle sunken, about 15 mm. long by 5 wide; there are about 15 pairs of pores in anterior series, and 18 in posterior. Posterior petals longer (17 mm.) and narrower (4 mm.), scarcely sunken; there are about 18 pairs of pores in anterior series, and 19 in posterior. Posterior end of test truncate, a trifle oblique, with slope downwards and forwards; periproct 8 mm. broad and 6 mm. high, covered by 60–70 plates, of which ten are much larger than others and form an outer marginal ring. Ventral surface of test flat on each side of sternum, but latter conspicuously keeled; keel about 11 mm. broad, 3 mm. high, and extending from labrum backward 27 mm. to a point about 15 mm. from lower margin of periproct, which we may call its posterior end; keel is highest, 9 mm. in front of this posterior end; seen from side, therefore, in natural position of test, keel slopes downward markedly from labrum for 18 mm., then slopes upward slightly for 9 mm., to its posterior end, whence test curves abruptly upward 10 mm., to a point on upper margin of subanal fasciole, about 5 mm. below periproct. Labrum slightly curved, but little projecting, 13 mm. from ambitus in furrow. Actinostome little sunken, about 8 mm. wide by 4 mm. long, covered by 30–40 plates, of which most anterior are largest. Bare ambulacral spaces on each side of sternum, about 6 mm. wide. Remainder of test quite closely covered with tubercles, except around actinostome; most of ventral surface is covered by primary tubercles which, however, pass into secondaries posteriorly, laterally, and on crest of keel. On dorsal surface, primaries few and inconspicuous; there are about fifteen small ones in posterior interradius arranged in half a dozen groups of two or three each; there are about ten slightly larger ones in each lateral interradius; and in each anterior interradius there are from twenty to thirty along margin of furrow, gradually passing into secondaries near ambitus. Sutural lines on dorsal surface, especially posteriorly, are slightly sunken and very distinct. Subanal fasciole consists of a broad band (varying from 1.5 to 2 mm.), enclosing an oblong space with rounded corners, about 13 mm. wide and about 8 mm. high (outside limits of fasciole, therefore, 17 × 12 mm.). Uppermost point of fasciole is about 3 mm. below periproct, while its lowest (or most anterior) point includes posterior end of sternum. — Genital pores 4, close together, practically at centre of dorsal surface. Whole test (except around mouth and on bare ventral ambulacra) thickly

covered with very slender, hair-like spines; secondaries and miliaries 1–3 mm. long and primaries up to 9 or 10 mm. in length; primaries, however, not conspicuously different or sharply distinguishable from secondaries. — Color of test pale purple, almost a grayish lavender, darkest in posterior dorsal interambulacrum and in band of subanal fasciole; spines silvery white.

2 specimens, Sagami Bay (35° 11′ N. × 139° 45′ E.), Japan, 50 fathoms. — 1 specimen, Sagami Bay (35° 3′ N. × 138° 48′ E.), Japan. Owston collection.

List of the species of Spatangus

purpureus O. F. Müller, 1776. Zool. Dan., p. 236. Norway to Azores, and in Mediterranean, 5–458 fathoms.

raschi Lovén, 1869. Öfv. Vet. Akad. Förh. Stockholm, p. 733. Norway to Azores, 100–805 fathoms.

lütkeni A. Agassiz, 1872. Bull. Mus. Comp. Zoöl., **3**, p. 57. Japan, littoral (?)–107 fathoms; Moluccas (Sluiter).

capensis Döderlein, 1905. Zool. Anz., **28**, p. 624. South Africa, 40–280 fathoms.

paucituberculatus A. Agassiz & Clark, 1907. Bull. Mus. Comp. Zoöl., **50**, p. 253. Hawaii, 127–286 fathoms.

altus Mortensen, 1907. "Ingolf" Ech., pt. 2, p. 131. "China Seas."

Key to the species of Spatangus.

Primary tubercles of dorsal side numerous, 150 or more in lateral and posterior interambulacra together.
- Subanal fascioled area more than twice as wide as high with a reëntering angle on upper side . . . . *purpureus.*
- Subanal fascioled area not nearly twice as wide as high, with no reëntering angle.
  - Only 2 pairs of ambulacral pores included within subanal fasciole on each side; anterior petals tapering towards ends, more or less decidedly so proximally.
    - Primary tubercles present in ambulacra between end of petals and ambitus; width of posterior petals less than one-fourth length . . . . . *raschi.*
    - Primary tubercles wanting in ambulacra; width of posterior petals more than one-fourth length . . . . *capensis.*
  - 3 pairs of ambulacral pores included within subanal fasciole on each side; anterior petals broad, not tapering towards ends, even proximally *altus.*

Primary tubercles of dorsal side few, less than 50 in lateral and posterior interambulacra together.
- Lateral ambulacra with two, one, or no primary tubercles; test very broad and flat, vertical diameter about equal to one-half length or less . *paucituberculatus.*
- Lateral ambulacra with from six to twelve primary tubercles; vertical diameter usually more than half the length.
  - Plastron with little or no keel; subanal fasciole 1–1.5 mm. broad; color deep purple . . . . *lütkeni.*
  - Plastron with conspicuous keel; subanal fasciole 1.5–2 mm. broad; color grayish lavender . . . . *pallidus.*

Maretia planulata.

Spatangus planulatus Lamarck, 1816. Anim. s. Vert., **3**, p. 31.
Meretia planulata Gray, 1855. Cat. Rec. Ech. Brit. Mus., p. 48.

3 specimens, about 45 mm. in length; Sagami Bay (35° 10′ N. × 139° 48′ E.), Japan. Owston collection.

Lovenia gregalis?

Alcock, 1893. Journ. Asiat. Soc. Bengal, **62**, p. 175.

1 specimen, 26 mm. long. Sagami Bay (35° 12′ N. × 139° 44′ E.), Japan, 60 fathoms. Owston collection.

Although there can be little question that this young spatangoid is a Lovenia, there is abundant room for doubt as to its being *gregalis*, for the specific characters are not yet evident.

Brissus carinatus.

Spatangus carinatus Lamarck, 1816. Anim. s. Vert., **3**, p. 30.
Brissus carinatus Gray, 1825. Ann. Phil., p. 9.

4 specimens, 56–93 mm. long. Sagami Bay, Japan. Owston collection.

Metalia spatagus.

Echinus spatagus Linné, 1758. Sys. Nat., ed. 10, p. 665 (= E. maculosus Gmel.).
Metalia spatagus Lovén, 1887. Ech. des. Linn., p. 162.

1 specimen, 28 mm. long. Sagami Bay (35° N. × 138° 41′ E.), Japan, 25 fathoms. Owston collection.

Schizaster japonicus.

A. Agassiz, 1879. Proc. Amer. Acad., **14**, p. 212.

4 specimens, about 50 mm. long. Sagami Bay (35° 22′ N. × 139° 40′ E.), Japan. — 1 specimen, Sagami Bay (35° 12′ N. × 139° 44′ E.), Japan. — 1 specimen, Uraga Channel, Gulf of Tokyo, Japan, 20–30 fathoms. Owston collection.

All but two of these specimens are badly crushed.

Schizaster ventricosus.

Gray, 1851. Ann. Mag. Nat. Hist., (2) **7**, p. 133.

4 specimens, about 30 mm. long. Sagami Bay, Japan. — 2 specimens, Tokyo Bay, Japan, 10 fathoms. Owston collection.

All but one of these specimens are badly crushed.

HOLOTHURIOIDEA.

Thyone anomala?

Östergren, 1898. Zool. Anz., **21** p. 110.

1 specimen, about 75 mm. long by 13 in diameter. Sagami Bay (35° 3′ N. × 138° 47′ E.), Japan, 110 fathoms. Owston collection.

The specimen is contracted, and having been preserved in formalin, the calcareous particles in the skin are entirely wanting, except a few perforated and somewhat corroded plates in the tentacles. The general anatomy agrees well with *anomala*, except that I found only a single stone-canal. Of course, without the calcareous particles of the skin, actual identification of a Thyone is impossible.

Holothuria monacaria?

Lesson, 1830. Cent. Zool., p. 225.

1 specimen, about 140 mm. long. Okinose, Sagami Bay, Japan. Owston collection.

This specimen is also strongly contracted, and the outer layer of calcareous particles appears to be nearly all dissolved; at least tables are very rare, while buttons with three pairs of holes are exceedingly common. The general appearance of the animal is very much like a Stichopus, for there is a series of large warts along each side and others are scattered over the back, while the ventral surface is thickly covered with pedicels. The deposits, however, seem to agree perfectly in form with those of *monacaria*, and I therefore refer the specimen to that species, although its condition is such as to leave room for doubt.

Molpadia rosacea, sp. nov.

Body stout, 100 mm. long by about 50 mm. in diameter; oral disc 15 mm. in diameter; caudal appendage very small, only 5 mm. long, and apparently without any anal papillae. Skin thin and smooth. Tentacles fifteen, of uniform size; each one is about 4 mm. long and 1 mm. in diameter; nearly a millimeter from the tip on each side is a very slender digit only a quarter of a millimeter long; no other digits are present. No evident genital papilla. Calcareous ring not very stout; radial projections posteriorly rather small and delicate. Polian vessel single. Stone-canal single, spirally wound in dorsal mesentery. Respiratory-trees well developed but slender; right one extending forward so far as to lie against calcareous ring. Calcareous deposits in body wall very scarce, consisting of irregular perforated plates, which have the appearance of having been discs of small tables; they are only 80–100μ across and have from two to six holes; most of them are colored and apparently becoming transformed into phosphatic bodies; these latter are exceedingly abundant but extraordinarily small, scarcely any exceeding 40μ in diameter; they are arranged in small groups which appear as

crowded colored patches on the skin half a millimeter or less in diameter. Although the color of these phosphatic bodies, when seen under the microscope, is yellowish brown with little trace of red, the color of the animal to the unaided eye is decidedly reddish. — Oral disc and caudal appendage very light gray; all other parts densely speckled, especially anteriorly, with minute patches of light dragon's-blood red (Ridgway's Nomenclature of Color); general effect, therefore, is light old-rose red.

1 specimen, Yenoshima, Sagami Bay, Japan. Depth unknown. Owston collection.

It is with no little hesitation that I add another to the already long list of Molpadias described from a single specimen, but I cannot assign this Japanese novelty to any species hitherto described. It is most nearly related to *M. intermedia* of the North Pacific, but is easily distinguished from that species by the absence of tables, the minute phosphatic bodies, and the color. The "Key to the Species of Molpadia," recently published (Smiths. Cont. Knowl., **35**, p. 158), will have to be modified as follows to include *rosacea*.

A. Anchors wanting, etc.
  B. Phosphatic deposits present, etc.
    C. No true supporting rods, etc.
      D. Tables of body often very irregular, distorted or incomplete, sometimes wholly wanting; disc seldom with more than eight holes (those in tail may have 20–30 holes).
        E. Tables with more or less distinct disc, having 2–8 or more (usually 3–6), holes often with irregular outline and marginal projections; sometimes with no spire, and thus reduced to small irregular plates with 2–8 perforations.
          F. Tables or plates of moderate size, 80–350μ in diameter, usually with only one spire.
            G. Tables often wanting in skin of body, present in tail; disc quite asymmetrical; spire of moderate height, etc.

. . . .

            GG. Tables (or perforated disc-like plates) present in skin of body; disc rather symmetrical with 3–6 or more holes; spire (when present) high.
              H. Phosphatic deposits more than 60μ in diameter; tables with spires; color not old-rose red.
                Discs, etc. . . . . *intermedia.*
                Discs, etc. . . . . *andamanensis.*
              HH. Phosphatic deposits very minute, 40μ or less in diameter; tables reduced to perforated disc-like plates; color old-rose red . . . . *rosacea.*
          FF. Tables, etc. *similis.*

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SOME NEW REPTILES AND AMPHIBIANS.

BY THOMAS BARBOUR.

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No. 12. — *Some New Reptiles and Amphibians.* By Thomas Barbour.

During 1906 and 1907 I was engaged in zoölogical collecting in India, Burma, and the Dutch East Indies. Collections in various branches of zoölogy were obtained, but special efforts were made to secure reptiles and amphibians in large series. For this reason Java, which is the type locality for a considerable number of forms, was rather extensively investigated. Happily with excellent results, as the time of year, December, 1906, and March and April, 1907, proved very favorable. Large numbers of natives were employed, and much aid was freely given by many of the Dutch officials, to whom thanks and credit will be given in the more detailed account of the collections. Thanks to the energy of Mr. Alan Owston of Yokohama, most excellent Japanese collectors have visited the Riu Kiu Archipelago and Formosa again and again, having provided thus a large part of the material which was used by Stejneger in his Herpetology of Japan and adjacent territory (Bull. 58, U. S. Nat. Mus., 1907). Subsequent Formosan collections have yielded the new species described here. Finally a collection replete in specimens of the highest interest was obtained from Mt. Wuchi in the interior of the island of Hainan. Concerning this region Boulenger wrote (P. Z. S., 1899, p. 956) the following on the receipt of the collections of the late Mr. John Whitehead: "The fact that so many of the few species represented in the collection are new, tends to show how rich a harvest these unexplored mountains would have yielded but for the fatal climate which has deprived the zoölogical world of one of its most enthusiastic and successful members."

Several new forms are here described from unidentified material which has long been in the collection here.

My sincere thanks are due to Dr. Stejneger, who has helped me in a most disinterested and generous way, and to Mr. Garman, whom for many years I have called on freely for advice.

REPTILIA

Goniurosaurus, gen. nov.

Digits moderate; otherwise exactly as in Aelurosaurus. Body covered with excessively small, flat juxtaposed scales and larger tubercle-like scales. Upper and lower eyelids well developed, as in Aelurosaurus (Geckonidae) and in the Eublepharidae. Pupil vertical. Tail elongate with whorls of scales proximally. That the tail is capable of being curled up is evident from its position in the type preserved in alcohol. Possibly this genus should also contain *Pentadactylus brunneus* Cope, which Boulenger placed provisionally in Aelurosaurus.

Goniurosaurus hainanensis, sp. nov.

Habit slender. Head depressed, subtriangular, distinct from neck; snout pointed, distance from anterior border of eye to tip of snout equal to distance from posterior border of eye to ear opening; ear opening a small, narrow, almost vertical slit. Body long, somewhat depressed. Limbs rather long, thin. Scales of top of head, body, limbs, and tail small, uniform flat granules, of varying shapes; among these on the back more or less regular longitudinal series of enlarged tubercular scales occur; these are also scattered over the upper surfaces of the limbs and are present on the proximal half of the tail in twelve whorls, which are not complete below. Scales of all the lower surfaces larger than the contour scales of the upper surfaces, polygonal, subequal. Male with twenty-nine preanal pores in an angular series. Rostral scale one and one-half times as broad as high; separated from the nostril by two enlarged superposed scales, the anterior nasals; the nostril lies behind these, and is surrounded elsewhere by small scales; it is not in contact with a supralabial. There are no other enlarged scales except the supralabials, ten in number, and a few enlarged granules on top of the nose. Mental large, an imperfect equilateral triangle. Tail long, slender, a little shorter than the distance from vent to tip of nose.

Color very dark brown, almost black; limbs brown, belly white. A white band reaching around the back of the head from eye to eye; a white band across body near the fore limbs, one across the middle of the body and one across the body near the hind limbs. Three white rings around the tail, which is almost black above and below. The extreme tip of the tail is white.

Type. — No. 7104, Mus. Comp. Zoöl., a single specimen, taken 16 November, 1906, on Mt. Wuchi, Central Hainan, by a Japanese collector of Mr. Alan Owston.

Glauconia carltoni, sp. nov.

Snout rounded; supraocular present, very small; rostral extending almost to level of eyes; about twice as broad as the nasal, which is completely divided into two; ocular bordering the lip for a considerable distance between two labials, the first of which reaches to the level of the nostril only; five lower labials. Scales

on body in 14 rows. Diameter of body 55 times in the total length, in length of tail 5.5 times; length of tail in that of body about 10.

Color very light brown above, ashy gray beneath.

Type. — No. 3749, Mus. Comp. Zoöl., Amballa, India, M. M. Carlton.

There are two other specimens in the collection, No. 3217, which show the same characters as the type.

The species is named for Rev. M. M. Carlton, who for many years made valuable collections in Upper India.

This new form evidently represents a localized race of *G. blanfordii* Blgr., known first from Sind, the type locality, and later from Northern Beluchistan (Alcock & Finn., Journ. Asiat. Soc., Bengal, **65**, p. 561). Its most noticeable divergence is its less elongate form.

Natrix aequifasciata, sp. nov.

Eye rather large. Rostral broader than deep, just visible from above; internasals almost wedge-shaped, twice as long as broad, one and one-half times as long as prefrontals; frontal one and two-thirds as long as broad, as long as distance from end of the snout, shorter than the parietals; loreal as long as deep; two preoculars and two or three postoculars; one or two suboculars may be present, — these are very small and separated by the fifth upper labial. Temporals 2 + 3, — these may be broken into several scales; nine upper labials, the seventh largest and the fifth always entering orbit, — the fourth and sixth may do so also, or they may be excluded by the suboculars; five pairs of lower labials in contact with anterior chin shields, which are a very little shorter than the posterior. Scales in nineteen rows strongly keeled, except the outer row; on which the carination is weak. Ventrals 148–151; anal divided; subcaudals 74–75.

Color (in alcohol) boldly banded with twenty or twenty-one black bars on the body and twelve on the tail. The interspaces narrower than the bars, but less narrow laterally than dorsally, white with a slight brownish tinge. Ventral surface ivory white, with black markings of the bars; these often end abruptly at the median line. The black blotches are roughly alternate.

Types. — No. 7101, Mus. Comp. Zoöl., two specimens, each about 20 cm. long, from Mt. Wuchi, Central Hainan. Taken by one of Mr. Owston's Japanese collectors.

This strongly differentiated species shows a probable relationship to both *N. tigrina* and *N. piscator.*

Cope's *Trimenodytes balteatus* (Proc. Acad. Nat. Sci. Phila., 1894, p. 426) probably represents an abnormal Natrix, which, however, cannot be identified with this species.

Pseudoxenodon stejnegeri, sp. nov.

Rostral just visible from above; internasals shorter than prefrontals; frontal almost one and one-half times as long as broad, shorter than distance to tip of

snout, much shorter than parietals; loreal as long as deep; two preoculars; three postoculars; temporals 2 + 2; eight upper labials, fourth and fifth entering orbit; five lower labials in contact with the anterior chin shields, which are very nearly the same size as the posterior. Eleven dorsal rows of scales keeled, only the dorsal 5 strongly; scales in nineteen rows anteriorly, in seventeen rows on middle of body, and in fifteen rows near the tail. Ventrals 153; anal divided; subcaudals in 68 pairs.

Color olive above, with an indistinct lateral series of dark blotches; head with a black stripe from posterior border of the orbit to the angle of the jaws; upper labials with sharp black markings along their posterior edges; upper lip yellowish; lower surfaces dull white, confluent dark olive puncticulations form three irregular bands, one along the middle and one on each end of the gastrosteges; there are many scattered spots elsewhere, also larger diffuse brown blotches. On the under surface of the tail the dots are irregularly scattered and produce a gray effect. Along the sides of the tail is a white line formed by spots on the outer end of each subcaudal scale. There are no spots on the throat, which is pure white. Length of body 370 mm.; length of tail 100 mm.

Type. — No. 7103, Mus. Comp. Zoöl., a single specimen, from Mt. Arizan, Central Formosa. Taken 29 November, 1906, by one of Mr. Owston's Japanese collectors.

This species seems to be, as would be naturally expected, related to *P. dorsalis* (Günther) from China. It differs in having two preoculars instead of one, in the number of ventral and subcaudal scales, and in coloration.

It is a privilege to associate with this interesting new species of a genus hitherto unrecorded from Formosa, the name of a kindly friend and generous helper, Dr. Leonhard Stejneger.

Holarchus nesiotis, sp. nov.

Nasal divided; rostral reaching far back above, completely separating the internasals and coming into contact with the prefrontals. Frontal very large, much longer than distance to tip of snout, longer than the parietals. Loreal square; two pre- and two post-oculars; temporals 1 + 2, the lower of the two temporals is the smaller, while the opposite is the condition in *H. formosanus* figured by Stejneger (Herp. of Japan, 1907, p. 355). Eight upper labials on each side, fourth and fifth entering eye; four labials in contact with anterior chin shield, which measure about one and one-third the size of the posterior. Scales in 19 rows, perfectly smooth. Ventrals distinctly angulate, 169; anal divided; subcaudals 56 pairs.

Color pale brown above, with an indistinct light vertebral line and four dorsal and dorso-lateral longitudinal bands of slightly darker brown. Sides and belly ivory white. On the parietals there are dark brown spots, also a symmetrical square brown, almost black, blotch below the eye on supralabials 5 and 6. A chevron-like band on the nape with its apex directed forward.

Type. — No. 7107, Mus. Comp. Zoöl., a single specimen, about 355 mm. long, from Ting-an, Hainan Island. Taken by a collector for Mr. Owston.

Related to *H. formosanus hainanensis* (Boettger), to which form Cope's *H. dolleyanus* (l. c. p. 423) must be considered a synonym. Boettger's paper (Ber. Senck. Nat. Ges. 1893–4) was received at the library of the Mus. Comp. Zoöl. Oct. 16, 1894. Cope's paper did not appear until Feb. 13, 1895.

Calamaria sondaica, sp. nov.

Rostral very nearly as deep as broad, easily visible from above; frontal a little longer than broad, considerably shorter than the parietals, a little more than twice as broad as a supraocular; one pre- and one post-ocular; diameter of the eye a little less than its distance from the mouth; five upper labials, the first nearly three times as large as the second, which is smaller than the third or fourth. These are subequal and enter the eye. The fifth is larger than the third and fourth together. A pair of infralabials in contact between the mental and the anterior pair of chin shields. Scales in 13 rows; ventrals, 154; anal entire; subcaudals 10. Tail rather obtuse. Dark reddish brown above (with fine plumbeous iridescence in life); six dark lines just visible on neck, very indistinct on body; rows of scales separated by zigzag white lines; a lateral white line on last row of scales. Ventral surfaces white (yellow in life), very heavily blotched with angular dark markings; a black line down midventral region of the tail and two black lateral lines on tail.

Type. — No. 7102, Mus. Comp. Zoöl., one specimen Buitenzorg, Java, April, 1907. T. Barbour, collector.

It is with great reluctance that this new species is described. No ophidian genus cries for a revision more than Calamaria. Nevertheless this new form seems to merit recognition on account of several distinctive characters.

Superficially, i. e. in coloration, this form does not bear the slightest resemblance to its nearest relative, which is *C. virgulata;* nor, it may be added, does it seem to agree with any of the forms which Boulenger (Cat. Snakes, 1894, **2**, p. 340), has considered synonymous with this species.

Calamaria albopunctata, sp. nov.

Rostral somewhat broader than deep; frontal longer than broad, much shorter than parietals, and less than twice as broad as a supraocular; one pre- one postocular; diameter of eye less than distance to mouth; five upper labials, first, third, and fourth subequal, second and fifth large; third and fourth entering orbit; first infralabial meeting its fellow behind the symphysial; two pairs of chin shields in contact with each other. Scales in 13 rows; ventrals 247; anal entire; subcaudals 14. Tail rather blunt. Dark brown above, a lighter band on occiput; two outer rows of scales with light centres; lower surfaces yellow with a few dusky markings; a blackish line along lower surface of tail.

Type. — No. 7106, Mus. Comp. Zoöl., one specimen from the East Indies.

Several years ago a collection of reptiles was offered for sale which purported to come from the Moluccas and was marked "Ternate or Amboina." Many of the specimens undoubtedly did come from the Moluccas. The Calamaria which is described above, reminds one strongly of *C. occipitalis* Jan, and very possibly will be found locally in some one of the many small areas in Java which are as yet unknown herpetologically. That we do not yet know completely the calamarian fauna of Java is attested by the fact that in April, 1907, at Sindanglaia in Western Java, a specimen of *C. sumatrana* Edeling was taken, thus adding a species to the list, already a long one, of forms known to inhabit Java.

Pseudelaps muelleri insulae, subsp. nov.

Rostral scale visible from above. The eye is somewhat greater in diameter than its distance from the mouth. The scales around the body are in 15 rows; the ventrals 146 and the subcaudals 19 pairs in number. The anal is divided. Total length 400 mm.; tail 32 mm. Boulenger's (Cat. Snakes, 1896, **3**, p. 317), measurements of *P. muelleri* are as follows: "Total length 500 millim; tail 70."

Color. In life this is almost coal black above with rich plumbeous iridescence when held in bright light. The ventral surface is, in general, dusky white. Along each of the gastrosteges runs a line of dark brown spots; these spots occur in a closely grouped cluster at the ends of each ventral scale. In the gular region the spots fuse and grow darker in color; the general effect is a very deep brown. On the lower labials small white spots occur, irregularly scattered. In alcohol, however, the black has changed to a very dark dull green and the brown markings below to an olive color.

Type. — No. 7080, Mus. Comp. Zoöl., one specimen, Djamna Island, Dutch Papua. T. Barbour, collector. Djamna is a small islet, situated off the Saär district between Cape D'Urville and Humboldts bay. It lies a few miles south-east of the Arimoa (Kumamba) group of islands.

This form differs from *Pseudelaps muelleri* (Schlegel) in having a much shorter tail, fewer pairs of subcaudal scales, and a distinctive coloration.

This subspecies may be identical with "*P. schlegelii* (Günther)," which seems distinguishable as a race of *P. muelleri* (Schl.). The color of this Djamna form does not, however, seem within the variation limits of any described form.

AMPHIBIA

Prostherapis equatorialis, sp. nov.

Snout depressed, projecting, rather pointed, truncate with angular canthus rostralis; loreal region slanting inward from below; nostril very close to tip of snout; interorbit very broad, slightly convex; tympanum very small but distinct, about one-third the width of eye. First finger slightly shorter than second; toes free; discs small; subarticular and inner metatarsal tubercles indistinct; no

outer metatarsal tubercle. The hind limb being carried forward along the body the tibio-tarsal articulation reaches the posterior border of the eye. Skin smooth above, tubercular on posterior part of belly and lower surfaces of thighs.

Color rich brown above, striped with darker, a narrow white vertebral line; all lower surfaces whitish. Male with a large subgular vocal sac.

Types. — No. 2261, Mus. Comp. Zoöl., two examples, from Equador.

For the sake of comparison with the above species I append a description of *P. femoralis* Barbour from Gorgona Island off the coast of Colombia.

Snout broad, depressed, with angular canthus rostralis; loreal region nearly vertical; nostril nearer tip of snout than eye; interorbital space somewhat broader than upper eyelid; tympanum indistinct but not quite concealed. First finger longer than second; rudiment of web between third and fourth toes; subarticular tubercles moderate, metatarsal tubercles small. The hind limb being carried forward along the body, the tibio-tarsal articulation reaches well beyond the eye. Skin smooth above and below.

Color gray above with faint brown marblings, below pale gray with rich chocolate markings, which are most abundant on the chin region.

Cacopoides, gen. nov.

An engystomatid related to Cacopus. The precoracoids are wanting, the coracoids meet each other on the median line, without an intercalated cartilage; the large metasternal cartilage, instead of being connected to the coracoids by an isthmus, much more narrow than the metasternum itself, is closely adpressed to the coracoidal symphysis. This may be made more clear by the appended drawings. Choanae small, with valve-like flaps; dermal ridges behind the choanae converging posteriorly and each with an enlarged papilla near the median line; another long ridge in front of the oesophagus which is sharply curved anteriorly near the median line. Tympanum hidden. Fingers free, toes webbed at base, tips not dilated. Sacral diapophyses rather strongly dilated.

Cacopoides borealis, sp. nov.

Habit very stout. Head small; mouth small; snout rounded; no canthus rostralis; snout about as long as orbital diameter; interorbital space more than twice the diameter of the upper eyelid. Fingers moderate, first shorter than second; toes moderate, webbed at base; no subarticular tubercles; two metatarsal tubercles, the inner strong and shovel like, the outer weak. Hind limb short. Skin smooth, the dorsal surface with scattered minute pits. Color dark brown-olive above; beneath dusky, marbled with brown. A subgular vocal sac is present.

Type. — No. 2436, Mus. Comp. Zoöl., one example, from Antung, Manchuria.

Dr. Stejneger has seen this specimen and doubts the correctness of the locality; he has suggested Autung in Kiang hsi. The specimen was, however, taken by a Japanese bird collector of Mr. Owston and from what Mr. Owston states and from

other specimens which were said to come from the same locality I feel that there is very strong circumstantial evidence that the locality is correct. It may possibly have been confused in Mr. Owston's laboratory with material from Hainan or Formosa, but even in this case would be nearly as far from its relatives as it would be in Manchuria.

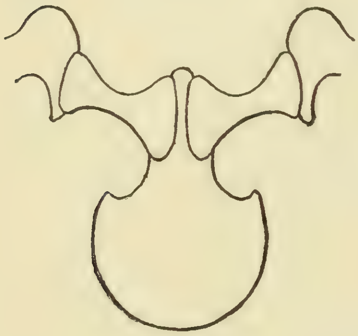

FIG. 1
Cacopus. — Pectoral girdle (after Boulenger).

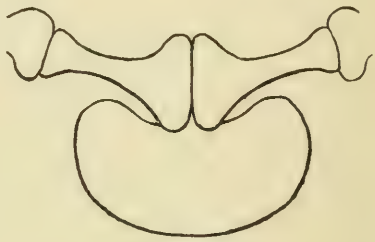

FIG. 2
Cacopoides. — Pectoral girdle.

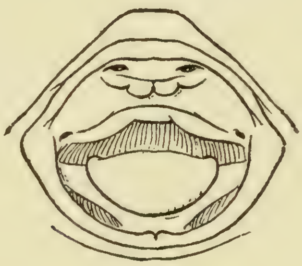

FIG. 3.
Cacopoides borealis. — Interior of mouth.

Microhyla hainanensis, sp. nov.

Habit stout. Snout rather rounded, longer than orbital diameter; interorbital space about equal to upper eyelid. Fingers moderate; first much shorter than second; fourth much the longest; toes moderate, nearly one-half webbed; tips of finger and toes not dilated; subarticular tubercles present, inconspicuous on fingers but very pronounced beneath the toes; two palmar tubercles, the outer by far the larger; two small metatarsal tubercles, the outer the more prominent. The hind limb being carried forward along the body the tibio-tarsal articulation reaches to or beyond the tip of the snout. Skin mostly smooth, with a few scattered tubercles on the posterior part of the back and a larger number on the outer sides of the thighs.

Color olive or pinkish brown in various shades; several chevron-like bands of a darker tone on the back; a dark band between the eyes which may be inter-

rupted on the median line; a dark band along each side and many cross-bars on the limbs; a large very dark brown — almost black — spot on each side of the vent. Throat and sides of chest clouded with dusky brown; the remainder of the lower parts immaculate. Male with a subgular vocal sac.

This form is evidently a near relative of *M. pulchra* (Hallowell), but is easily distinguished by the stout form of body and hind limbs, the scattered tubercles, and the conspicuous black spots.

Types. — No. 2435, Mus. Comp. Zoöl., four specimens from Mt. Wuchi, Central Hainan. Taken by a Japanese collector of Mr. Alan Owston.

Ceratophrys intermedia, sp. nov.

Vomerine teeth in a slightly interrupted series between the choanae; this series is not quite straight as in *C. fryi*, but the two halves point slightly backward on the median line. The first and second fingers are of very nearly the same size, the first slightly longer than the second. The color and granulation of the back is the same as in *C. boiei* except that there is no conspicuous brown spot below the eye; and there is a white band joining the orbits.

Type. — No. 2254, Mus. Comp. Zoöl., from Santa Katharina, Brazil.

This species stands between *C. boiei* Wied, and *C. fryi* Günther.

Bufo bankorensis, sp. nov.

Habit very similar to *B. himalayanus* (Günther) and *B. melanostictus* Schneider. It differs markedly from the former in the smoother crown, in that the warts on the upper surfaces of the body, and especially on the legs, are much smaller, more scattered, and subequal. It differs conspicuously from the second mentioned species in the absence of the cephalic ridges.

Crown deeply concave, smooth; ridges between eye and nostril very weak; snout short and blunt; interorbital space much wider than upper eyelid; tympanum small, vertically oval, partially covered by a fold of skin. First finger a very little longer than second; a small inner and an outer palmar tubercle, which is nearly three times as large as the inner one; subarticular tubercles single, rather prominent. There are many other tubercles on palm and digits. The hind limb being carried forward the tarso-metatarsal articulation reaches beyond the tip of the snout; toes less than half webbed, the webs with their outer edges denticulate; small, single, subarticular tubercles on all but fourth toe, where they are double; two subequal metatarsal tubercles, the inner the more prominent; lower surfaces of feet richly tuberculate like the hands. A slightly developed tarsal fold more conspicuous in the male than in the female. Upper surfaces with subequal warts well separated by areas of smooth skin; in the female specimen the warts show a tendency towards spinosity. The parotoid glands are large, suboval, or tending toward kidney shape. I do not find an internal vocal sac in the male; in this particular especially is the tendency toward

B. himalayanus. In the specimen of this sex nuptial asperities are present on the first and second finger.

Color (in alcohol) dark brown above, lighter below; a blackish band begins at posterior border of eye, covers the lower half of the paratoid gland, and runs along the side, ending in a series of spots. In the female many of the warts have black apices, a character frequent in *B. melanostictus.*

Type. — No. 2432, Mus. Comp. Zoöl., two specimens, a male and female, Bankoro, Central Formosa. Taken by a Japanese collector of Mr. Alan Owston.

This strongly marked species is evidently closely related to *Bufo melanostictus;* it also tends towards *Bufo himalayanus.* This opinion is also held by Dr. Stejneger, who has most kindly examined the types.

Hyla kampeni, sp. nov.

Tongue subcircular, slightly nicked and free behind. Vomerine teeth in two short groups between the middle of the choanae, the interspace separating them as wide as one of the groups. Snout rounded, tympanum round; its diameter is equal to two-thirds of the distance from eye to nostril. Rudiment of pollux present. Fingers webbed as follows: second digit two-thirds, third wholly, fourth almost wholly, fifth wholly. The toes are all wholly included in the extent of the web. Discs large, almost as large as tympanum. Skin smooth above, belly and lower side of thighs finely granulate. Upper surfaces greenish brown (dull green in life), lower surfaces unmarked yellow.

Type. — No. 2433, Mus. Comp. Zoöl., a single specimen, taken at Wahaai, Ceram, January, 1907, by T. Barbour.

Hyla kampeni is nearly related to *H. montana* Peters e Doria. It may be readily distinguished by its larger tympanum, greater extent of webbing between the toes, and a more slender build. It is also evidently different from *H. amboinensis* Horst and H. ruepelli Boettger, which we might expect to find in this locality.

Recently Dr. P. N. van Kampen has produced (Max Weber's Zoologische Ergebnisse einer Reise in Niederländisch Ost-Indien, 1907, **4**, pt. 2, p. 383–418, pl. 16) a most excellent piece of work in which he tabulates the ranges of East Indian Amphibians so far as they are known. He records *Hyla dolichopsis* Cope and *H. vagabunda* Peters e Doria as the only ones hitherto known from the island of Ceram.

This species is named for Dr. van Kampen, friend and companion in travel in the Dutch East Indies.

Van Kampen has shown (Nova Guinea, **5**, Zoölogy, p. 176) in a recent account of New Guinea Amphibians that it is probable that the young of several species of Hyla lack vomerine teeth. Is it not, then, also possible that this may be the case with some adults? Answering this in the affirmative he recommends that Hyla and Hylella be united. He also notes that Gadow (Amphibia and Reptiles, 1901) has remarked that owing to the wide discontinuity of the range of

Hylella it cannot be considered a monophyletic genus. The occurrence of three species of tree-toads lacking vomerine teeth, on the comparatively small island of Jobi, is rather remarkable.

Hyla ouwensii, sp. nov.

Head short; snout squarish; loreal region rather concave; tympanum extremely small, about one-fifth diameter of eye; the tibio-tarsal articulation reaches a considerable distance beyond the snout. Fingers two-thirds webbed, toes three-fourths webbed. Skin of back rough but without enlarged tubercles, skin on belly with very many small tubercles; these are largest and most abundant about the anal region, whence the series extends out on to the inner sides of the thighs for about half their length. Upper parts of head, body, thighs, shins, feet, and arms of a grayish ground color vermiculated and blotched with blue, in alcohol; green, in life; more ashy gray shows on the limbs than on the back. Throat white, belly and lower sides of hind limbs yellowish.

Allied to *Hyla* (*Hylella*) *nigromaculata* (Meyer).

Type. — No. 2434, Mus. Comp. Zoöl., a single specimen, about an inch and a half long, taken at Pom, north coast of Jobi (Japen) Island, Geelvink Bay, Dutch Papua, February, 1907. T. Barbour, collector.

This species is named for Major P. A. Ouwens, Curator of the Buitenzorg Museum, Java, who gave me a most kind hospitality, much assistance, and information.